THE SPECIALISTS' SERIES

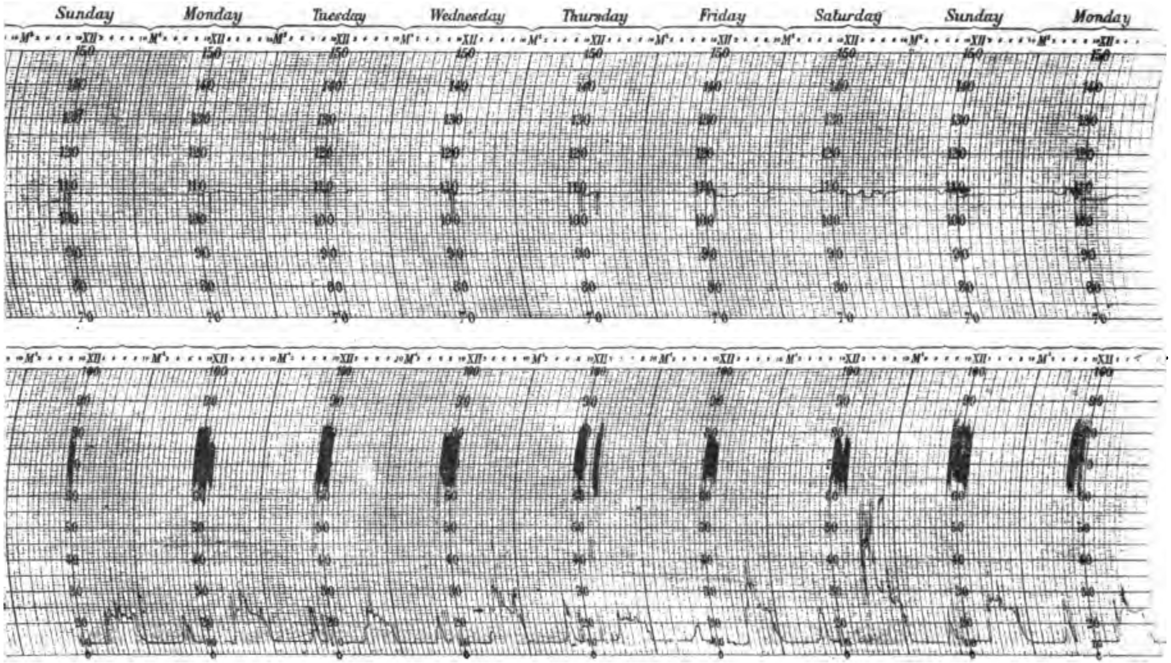
TELFORD

ELECTRIC LIGHT INSTALLATIONS.

VOLUME III.

APPLICATION.

Frontispiece



Double Chart from a registering apparatus.
The upper chart indicates the voltage, and the lower one the current. (See page 138)

ELECTRIC LIGHT INSTALLATIONS.

VOLUME III.

APPLICATION.

A Practical Handbook

BY

SIR DAVID SALOMONS, BART., M.A.,

VICE-PRESIDENT OF THE INSTITUTION OF ELECTRICAL ENGINEERS.
ASSOCIATE OF THE INSTITUTION OF CIVIL ENGINEERS.
MEMBER OF THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.
MEMBRE DE LA SOCIÉTÉ INTERNATIONALE DES ÉLECTRICIENS.
MEMBER OF THE PHYSICAL SOCIETY OF LONDON.
FELLOW OF THE ROYAL ASTRONOMICAL SOCIETY.
FELLOW OF THE CHEMICAL SOCIETY.
ETC., ETC., ETC.

SEVENTH EDITION, REVISED AND ENLARGED.

WITH 33 ILLUSTRATIONS.

An Edition, mostly re-written, of "Electric Light Installations and the Management of Accumulators."

LONDON:
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1894.

EXPLANATORY.

VOLUME I. dealt exclusively with accumulators and their management; Volume II. described a large variety of apparatus required in connection with electric light and power, and gave a few explanations concerning such appliances; but, so far, nothing has been said on the best methods of working, which may broadly be taken as coming under the head of practice. This should include not only the arrangement of the various requirements for using electric energy, but also the most effective methods of working, as well as mechanical details which interest both the engineer and the workman. While dealing with these subjects in the present volume, it has become necessary in a number of cases to repeat afresh what has been stated in preceding parts of the work, in order that the reader may avoid the trouble of having the other volumes constantly before him, and the inconvenience of continual reference to them. The intention the writer has always had in view is to make each volume as complete in itself as possible. He assumes that Volume II. will be consulted when information is needed as to selection of types of apparatus and as to the purposes for which electric energy may be employed. This volume is prepared on the assumption that the details of an Installation have already been settled, and that all the intending user now desires to know is the most efficient method of proceeding in order to produce, as near as practicable, the best results. A considerable amount of theoretical matter must naturally enter into a subject of this kind, for it is impossible for anyone to

decide precisely as to what another will do in some special circumstances. In such a case, it is frequently of importance to the reader that he should have set before him the various alternatives, and theory often enters to form a decision. It must be borne in mind that many points here described are not positively essential, except to the expert; and for that very reason it has been deemed advisable to include a few remarks on such matters.

Footnotes have been studiously avoided throughout the three volumes, since they have a tendency to distract the attention of the reader.

The object of publishing this edition in three volumes is to place before the reader, as soon as possible, all information up to date, and to leave the writer at liberty at a future time, should it be found necessary, to issue a fourth volume by way of a supplement, without the unavoidable delay of preparing a new edition.

Many figures and calculations occur in this volume; every care has been taken to check them, and it is hoped that no errors, due to oversight, have crept in.

In one of the chapters of this book a few remarks are made as to the possibility of the existence of life being simply an electric phenomenon. The reader must not regard what is said there as being necessarily the author's personal views upon the subject, nor must the argument be considered from a religious or irreligious stand-point. This view would be incorrect, since nothing definite has, so far, been proved for or against such a theory. At the same time, it may be reassuring to many to know that if, at any future period, the existence of life should be proved to be an electric phenomenon, all questions as to whether revealed religion is true or not would in no way be affected.

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CHAPTER I.

PRECAUTIONS.

WHEN a man of business enters upon any transaction, he will wisely weigh the risks to be encountered before he considers the question of profits. This principle is applicable to all that a man does in life, with regard to electric lighting no less than in other matters. Therefore, before proceeding with the practical part of the work necessary in using electric energy, what is to be avoided should be considered. The main risks, which have to be eliminated, are (1) chance of fire; and (2) danger to life.

Numbers of rules have been drawn up relating to the points requiring attention, when an installation is erected. A general set of rules was prepared by a committee of the Institution of Electrical Engineers. These rules, which were confirmed by the Council before publication, are so general in their character as to form a very incomplete guide to a practical man. Mr. Heaphy, of the Phœnix Fire Insurance Company, has published a set of rules which are more detailed. The chief objection, however, to these regulations is

that, in some parts, the details are too restricted ; and in other cases the matters to be decided by the Inspecting Engineer are left too much in his hands. Many other Insurance Societies and Institutions publish rules, but in no instance are they absolutely complete ; for the simple reason that it is impossible to lay down conditions which would meet every emergency. Many points have to be settled according to the nature of the situation in which the work is placed and other surrounding circumstances. A chapter on the subject of Precautions may appear alarming, but it is a recognised fact that, when the cheap-jack element has been eliminated and all the work is thoroughly well done, and all wiring is of such a size as to leave a considerable margin of safety, there is far less chance of accident with the electric light than with any other form of illuminant known at the present time. It cannot be too much insisted on that to accept the lowest tenders for work to be done is, in the majority of cases, courting a danger upon the premises. On the other hand, it does not follow that a high tender will necessarily produce good work : hence the question will be asked, how is the householder to protect himself ? There is but one way, and that is by employing a Consulting Engineer of good repute, whose interest will be to protect his client. The supposition, so often entertained, that the fee paid to him is a sum tacked on to the contract price, and, therefore, an expense which might be dispensed with, is quite an erroneous one. In practice it will be found that, apart from any question of the engineer seeing that the work is carried through in a proper manner, he will be able to select for his client one of the low tenders and see that bad work is not put in. Moreover, he will prob-

ably discover many little extras and other arrangements which are unnecessary, so that in the final result the Consulting Engineer's employer will not only be protected, but probably be saved expense besides, notwithstanding that a fee will have to be paid. In numerous instances it has come within the author's knowledge that the sum saved by the employment of a Consulting Engineer has been of enormous advantage, morally and pecuniarily, to those who engage his services. Although the electric light is gradually becoming general, the public at large have not yet had sufficient experience to enable them to understand the subject; nor is it likely that they will ever master it in the same way as they do gas and lamps. The patience and time needed to comprehend the many theoretical points which enter into electric work will be acquired only by a few. It is very much the same thing as when a man builds a house; although the building trade has existed for thousands of years, and everybody has seen houses in course of construction at all times of life, yet few persons are competent to undertake the task of erecting a house without employing an architect. No one not possessing special knowledge of the building trade would attempt to construct his house under the estimate of a builder, without calling in an architect to protect him. If he did not consult such an adviser, his friends would regard him as insane, and very rightly so.

The fact remains that there have been many fires in London, and in other parts of the country, due to the electric light having been used on the premises. No doubt, in every instance bad or careless work was the origin of the accident; yet it must be borne in mind that there is a danger exceedingly difficult to guard

against, and to be avoided only by the most careful laying, testing, and supervision. It is the formation of an arc, if the conductor should break. In the early stage of electric lighting each conductor consisted of a single wire, stranded cable being employed for mere convenience in the larger sizes, on account of the greater ease with which it may be bent. At the present moment, stranded cable is used even for the smallest kinds of wire. The argument against the first kind of cable was that the continuity of the circuit rested entirely on one wire, which might break and possibly an arc be set up at the fracture and lead to a fire. This is apart from the question of the inconvenience which might arise by inability to obtain a light beyond the fracture, even if no such arc were started. On the other hand, the advantage of this system is that it can be very fairly protected by a fuse, if of a reliable kind. Those who favour the stranded conductors say that it is easier to bend around angles without risk of breakage, and before the possibility of an arc being formed by fracture several wires must break; which is unlikely to happen. Apparently, no objections have been raised to stranded conductors.

The author will here indicate the weak points. These are very serious. One is that no stranded cable can be effectually protected by a fuse, for the simple reason that, if the fuse ensures the safety of the strand as a whole, it is quite clear that, should one or two of the wires break, such a fuse would be too large to protect the remaining wires. Consequently, the greatest possible care should be taken in laying stranded conductors lest any single wire be broken in its course; for it is evident that if several wires were to snap, there would be the probability of a long length of conductor being raised

and maintained at a very high temperature, even to that of red or white heat ; which might create a fire at once. The utmost caution ought, therefore, to be exercised, not only in laying the stranded cable, but in testing for continuity as well as for earth and short circuit. The only way to protect a multiple conductor, to which class a stranded cable belongs, is to insulate every wire in the strand and let it have its own fuse, or to lay every conductor in a fireproof casing. Both these methods cannot be resorted to in practice on account of the expense, although it may be worth while to do this where the light is used in buildings, the contents of which are of great value (and, if destroyed, no money would replace), and where explosives exist.

Very curious facts have come to the author's knowledge concerning the varying periods of lamp-life in different houses, though the lamps used were identically the same One gentleman made the remark that his house had been most beautifully wired, for his lamps, he said, lasted so much longer than those of a neighbour who used the same kind of lamp and received the same electric pressure. The London Electric Light Supply Corporation appear to have had a similar experience, in regard to the lasting power of lamps in houses upon the same circuit and situated close together ; householders, in some instances, complaining of an undue destruction of their lamps, whilst others had no fault to find. Of these results the author has found the solution ; they are due simply to the size of the conductors throughout the house. If in two electrical systems, both under the same conditions, the lamps in the one case last longer than in the other, this is owing to the difference in the resistances of the conductors. Consequently, if the lamps in two

houses, under the electrical conditions mentioned, last for a shorter period in the one house than in the other, it shows that the wires, in the latter case, are better as regards sectional area; since less pressure is absorbed in the wires before reaching the lamps, and less heat generated in the conductors. It may, therefore, be concluded that, if the insulation in both be equally good, the house in which the lamps are short-lived is the safer one to reside in; and that, to prevent lamp destruction, lamps should be inserted requiring rather higher voltage.

The rules issued by the Institution of Electrical Engineers will be set forth in full for the benefit of those who may wish to consult them. The author feels some reserve in criticising these rules, for, having been a member of the committee, it would not be acting in good faith to make public many of the pros and cons which arose in the discussion of each rule before its present form was settled. The rules are very general, because it was found absolutely impossible to provide for every emergency which might arise, without drawing up, what would actually have become, a voluminous specification for the contractor. This was never intended, and would no doubt have pressed hardly on the electric lighting industry, as well as on the users, by insisting on most stringent regulations simply because at times special cases might warrant them. Two or three points of interest may be remarked upon.

Rule I. is excellent, and speaks for itself. Even under the maximum limit mentioned there, if 150° F. is not reached, no good insulation existing is injured in the slightest degree. On this point the committee had ample evidence, and this rule is better than any one previously published for ascertaining the required sectional area in

all cases. The old rule of 1,000 amperes to the square inch section can rarely be applied, for very small wires will carry three times this current with safety; and large cables must carry less than that permitted by the 1,000 amperes rule. The temperature method settles all points. A special paraffin wax, softening at 130°, may be employed as a rough, but very practical, thermometer. Too high a temperature causes the insulation to give off vapours, which can be perceived by the sense of smell; but such heating should be avoided, because the insulation would be injured thereby. It was also shown that Rule 4 was a good one, and was generally complied with.

There is still a great difference of opinion, in reference to the use of cut-outs, as to how far they should be multiplied. Some experts consider the fewer there are of these apparatus the better, while others argue in the contrary direction. One thing, however, is quite certain, if the construction of the lamp holders, and any apparatus that may be employed on the lines, is such that by no possibility can a short circuit be produced while renewing a lamp or during any other operation, also provided the wires are properly laid, so that no short circuit can occur in the mains or branches, fuses may be completely dispensed with, and a number of bad contacts avoided. These improvements must be waited for, and, though slowly, they will surely come.

However, every motor, unless its present construction be completely revolutionised, should have a cut-out; for in these machines a short circuit is always possible. Access to the motor itself is frequently necessary, and at such times, if care be not exercised, a short circuit may be created. This might occur on other occasions, but at those times such accidents may be prevented by enclosing

the motor in a case. All motor covers should be so made as to freely admit the air to the motor in order that its circuit may be kept cool, and should be lined with a fireproof lining, as a protection against the possibility of sparking at the brushes.

As electric lighting becomes more general, and experience is gained, so trained men and improved apparatus will arise for this special trade. Then the danger of fire will be found to be no greater than when using gas, with the additional safety of freedom from explosion, and many of our present precautions will be ridiculed as uncalled for.

There is danger which cannot be met by fuses: it is the possibility of a conductor breaking, and the ends remaining in close contact, thus setting up an arc. In a single-wire conductor, the lamp will burn dull, and give an indication of this occurrence; but it does not necessarily follow that, because a lamp is dull, an arc exists, for other causes may produce it. In houses, all conductors carrying over two amperes should, as a general rule, be of stranded cable, so that the possibility of the breakage of one conductor setting up an arc shall not occur. Stranded cable also permits of short turns, without risk of fracture. On the other hand, very small wires are probably best in the unstranded form.

Every day brings fresh experience. An accident, which occurred in the author's workshop, may here be recorded, with the view of preventing such mishaps in future. An experimental lamp was attached by a flexible twin cord to a wall connector, which had no switch of its own, the only connector in the installation so arranged. The switch on the lamp was off, so no current passed. On his entering the workshop one

evening, he found the twin cord in flames, the fuse remaining intact. After the fire had been extinguished, a careful examination of the cord was made, and it showed very imperfect insulation. At one point the two wires had become bare, and there an arc had been started, which eventually fired the insulation and its covering. A rapid contact and separation must have occurred to set up the arc, for only 100 volts existed on the lines, and this infinitesimal quantity of current started the fire.

But for the good fortune of having discovered the occurrence at its outset, there can be little doubt that a serious fire would have resulted.

The moral of such accidents is not to dread electricity, but to have all wire, used in flexible twin cords, well insulated, and never to have the pressure of the current on such wires except when required; which may be effected by placing a switch in connection with every wall, and other, connector.

It cannot be too strongly pointed out that the leakage of electricity can be detected only by testing with proper apparatus, and not by the sense of smell, in the same way as gas. Under some circumstances, a leakage may be observed by the sense of touch, but naturally this test is not one which should be relied on.

With regard to transformers, although much information has recently been forthcoming on the subject of these apparatus, in consequence of the important place they are now taking in the distribution of current for public purposes, yet there is a great deal more to be done; and, as our leading electricians are now devoting all their energies in this direction, it may be hoped that before long the best methods of using and constructing

such apparatus will be brought forward. The laws which apply to transformers are now almost as well understood as apparatus concerned with continuous currents.

The following are the Regulations laid down by the Institution of Electrical Engineers :—

RULES AND REGULATIONS FOR THE PREVENTION OF FIRE RISKS ARISING FROM ELECTRIC LIGHTING. ISSUED BY THE SOCIETY OF TELEGRAPH-ENGINEERS AND ELECTRICIANS.

Revised and Remodelled from the Rules issued by the Society in 1883, *and from other sources of information both home and foreign, and recommended by the Council in accordance with the Report of the Committee appointed by them to consider the subject.*

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These General Rules are drawn up with the object of reducing to a minimum, in the case of the electric light, those risks of fire which are inherent to every system of artificial illumination, and also for the guidance of those who possess, and those who contemplate having, electric lighting apparatus on their premises.

It is to be understood that these general rules are not intended to supersede any detailed rules which fire offices may issue for their own protection.

It would, therefore, be desirable that, before the electric light is used, notice should be sent to the fire office in which the building is insured, in order that an opportunity may be given for inspecting the installation.

The chief difficulties which beset the electrical engineer are internal and invisible, and they can only be effectually guarded against by testing with special apparatus and electric currents; they arise from leakage and from bad connections and joints, which lead to waste of energy, and the production of heat to a dangerous extent.

In addition, the difficulties arising out of defective and inefficient apparatus are numerous; they must be understood and guarded against.

The necessity cannot be too strongly urged for guarding against the presence of moisture, which leads to loss of current and to the destruction of the conductors and apparatus by corrosion and otherwise.

Injudicious connections of any part of the circuit with the "earth" tend to magnify every other source of difficulty and danger.

Many of the dangers in the application of electricity arise from ignorance and inexperience on the part of those who supply and fit up inadequate plant, and

frequently from injudicious economy on the part of the user.

The greatest element of safety is, therefore, the employment of skilled and experienced electrical engineers to specify the method in which the work is to be done and the quality of the materials to be employed, and to supervise the execution of the work.

CONDUCTORS.

1. They must have a sectional area and conductivity so proportioned to the work they have to do, that, if double the current proposed is sent through them, the temperature of such conductors shall not exceed 150° F.

2. The conductors, or their casings, should be placed in sight if possible; and they should always be as accessible as circumstances will permit.

3. Within buildings they should all be insulated; and this rule applies equally to all conductors and parts of fittings which may have to be handled.

4. Whatever insulating material is employed, it should not soften until a temperature of 170° F. has been reached, and in all cases the material must be damp-proof.

5. When leads pass through roofs, floors, walls, or partitions, and where they cross or are liable to touch metallic substances, such as bell wires, iron girders, or pipes, they should be thoroughly protected by suitable additional covering; and where they are liable to abrasion from any cause or to the depredations of rats or mice, they should be encased in some suitable hard material.

6. In the case of portable fittings with which flexible leads are used, special precautions must be taken.

7. Conductors should be kept as far apart as circumstances will permit, the spacing between them being governed by their potential difference.

8. When conductors are carried in very inflammable structures, precautions should be taken to isolate them therefrom.

9. Conductors which are protected on the outside by lead, or metallic armour of any kind, require the greatest care in fixing, on account of the large conducting surface which would become connected to the core in the event of metallic contact between them.

10. In cases where conductors pass into a building, from one building to another, or from one room to another, precautions should be taken to prevent the possibility of fire or water passing along the course of the conductors.

11. All joints must be mechanically and electrically perfect, to prevent heat being generated at these points. When soldering fluids are used in making joints, the latter should be carefully washed and dried before insulation is applied.

12. Under all circumstances complete metallic circuits must be employed. Gas and water pipes must never form part of the circuit, as their joints are rarely electrically good, and, therefore, become a source of danger.

13. Overhead conductors, whether passing over or attached to buildings, must be insulated at their points of support. Precautions must be taken to obviate all risk of short-circuiting where they are likely to touch a building or other overhead conductors and wires, either by their own falling or by being fallen upon by other conductors.

14. In the case of overhead wires, every main should have a lightning protector at each point where it enters or branches into a building.

15. Metal fasteners for fixing conductors should be avoided; but, when unavoidable, some additional covering should protect the conductor from mechanical injury at such fixing points.

16. The insulation of a system of distribution should be such that the greatest leakage from any conductor to earth (and, in case of parallel working, from one conductor to the other, when all branches are switched on, but the lamps, motors, &c., removed) does not exceed one five-thousandth part of the total current intended for the supply of the said lamps, motors, &c.; the test being made at the usual working electro-motive force.

17. It will often be found a great convenience and assistance in the prevention of accidents if the positive lead be coloured differently to the negative, or made otherwise distinguishable.

SWITCHES.

18. Every switch or commutator should be of such construction as to comply with the following condition, namely, that, when the handle is moved or turned to and from the positions of "on" and "off," it is impossible for it to remain in any intermediate position, or to permit of a permanent arc, or heating.

19. The handles of every switch must be completely insulated from the circuit.

20. The main switches of a building should be placed as near as possible to the point of entrance of the conductors, or to the generators of the current if they are

within the building itself. Switches should be provided on both leads.

21. Switch-boards should bear clear instructions for their use by the inexperienced.

ELECTRICAL FITTINGS GENERALLY.

22. Switches, commutators, resistances, bare connections, lamps, &c., must be mounted on incombustible bases. Cut-outs mounted on bases of wood rendered uninflammable are admissible. Vulcanite bases are undesirable in damp situations. The cracking of porcelain and earthenware fittings is a source of danger which can be avoided by precautions in fixing.

CUT-OUTS.

23. All circuits should be protected with cut-outs; and all leads from the mains, or small conductors from larger ones, must be fitted with cut-outs at their branching points.

24. Where fusible cut-outs are used, the section should be so situated within its frame that the fused metal cannot fall where it may cause a "short circuit" or an ignition.

25. For all main conductors a cut-out should be provided for both the "flow" and "return," and the two fusible sections must not be in the same compartment.

26. The flexible leads of portable fittings must in all cases be protected by cut-outs at their fixed points of connection.

ARC LAMPS.

27. Arc lamps must always be guarded by lanterns or netted globes, so as to prevent danger from ascend-

ing sparks and from falling glass and incandescent pieces of carbon.

28. All parts of the lamps and lanterns which are liable to be handled (except by the persons employed to trim them) should be insulated.

THE DYNAMO.

29. The armatures and field-magnet coils should be thoroughly insulated. Dynamos should always be fixed in dry places, and they must not be exposed to dust flyings or other industrial waste products carried in suspension in the air. They should not be permitted in the working-rooms of mills, where the liability to such danger exists, or where any inflammable manufactures are carried on or inflammable materials are stored.

30. Motors should be subject to the same conditions; but when it is necessary to use them in positions such as those above referred to, they must be securely cased in, such cases having a non-combustible lining.

BATTERIES.

31. Both primary and secondary batteries should be placed and used under the same precautions as prescribed for dynamos; and the room in which they are placed should be well ventilated. The batteries themselves must be well insulated.

TRANSFORMERS.

32. When these are used to transform either direct or alternating currents of high electro-motive force—that is, from or to an electro-motive force of, say, 200 volts—they, together with their switches and cut-outs, must be

placed in a fire and moisture proof structure—preferably outside the building for which they are required. No part of such apparatus should be accessible except to the person in charge of their maintenance.

33. In all cases conductors conveying currents of high electro-motive force inside buildings must be specially and exceptionally insulated, cased in, and the casing made fireproof.

34. The positive and negative terminals connected to such conductors should not be permitted to be nearer each other than 12 inches.

35. Transformers which, under normal conditions of load, heat above 150° F., should not be permitted to remain in use.

36. Transformers should be so constructed that under no circumstances whatever should a contact between the primary and secondary coils lead the high E.M.F. into the building.

MAINTENANCE.

37. The value of frequently testing and inspecting the apparatus and circuits cannot be too strongly urged as a precaution against fire. Records should be kept of all tests, so that any gradual deterioration of the system may be detected.

38. Cleanliness of all parts of the apparatus and fittings is essential to good maintenance.

39. No repairs or alterations must be made when the current is "on."

All the above rules, for the reduction to a minimum of the risks from fire, are also applicable in principle to installations of electricity for other uses than that of lighting; they also include precautions necessary to

avoid risk of injury to persons, whether the conductors and apparatus are situated inside or outside a building.

A few other precautions have to be taken, and it may be well to give those which should be adopted with regard to Lord Kelvin's instruments, as they are now so largely in use. Naturally these precautionary measures apply only to cases when dangerous currents have been measured. The Rules have been laid down by Lord Kelvin himself.

PRECAUTIONS FOR SAFETY IN THE USE OF LORD KELVIN'S ELECTROSTATIC VOLTMETERS IN CONNECTION WITH DYNAMOS, WHETHER FOR DIRECT OR ALTERNATE CURRENTS.

1. In all applications in which one of the two conductors connected with the voltmeter is kept permanently connected with the earth, this conductor should be connected with the outer case of the voltmeter. The other is to be connected with the insulated terminal, and must be carefully guarded against accidental contacts.

2. To provide for use in any application not fulfilling the condition of section 1, all the electrostatic voltmeters are supplied with thoroughly insulating feet; and the precautions stated in section 3 and section 5 must be observed.

3. The vertical-scale voltmeter for from 400 to 12,000 volts, when set up for permanent use, should be enclosed in a case (which may be of wood with a glass front) preventing any person from accidentally touching

the metal case or the terminals of the instrument. The vibration-checker is worked with perfect safety by a silk cord passing through the wood or glass of the protecting-case to the front outside. For temporary or experimental applications the user must take his own precautions; an outer enclosing glass case might be found too cumbrous.

4. For ordinary domestic electric lighting or other applications to less than 200 volts, the multicellular voltmeter may be left unprotected so far as personal danger is concerned; but, to avoid chances of damage to instruments or wires, or of melting a fuse, its outer case, as well as its terminal insulated from the outer case, ought to be perfectly guarded against accidental contacts when the instrument is set up for permanent use. Glass and vulcanite sheaths are provided for this purpose by the instrument-maker when desired.

5. *General warning.*—Never open the case of the vertical-scale voltmeter to change its weights, nor touch its terminal to connect or disconnect (or to secure either connection if imperfectly made), without being sure either that the dynamo is not running, or that both the conductors leading to the voltmeter are safely disconnected from its circuit.

6. It may be asked, with reference to the vertical-scale voltmeter, why is the inner case made of metal? The answer is, that the electric conditions for definiteness of measurement require the vane to be protected all round from sensibly disturbing influence of any substance other than the air around it, differing in potential from itself unless at the same potential as the quadrants. Why, then, not coat the metal inner case with wood or vulcanite or other non-conducting material?

Answer: The protection thus imagined might be delusive when 10,000 volts is dealt with. Safety is more surely secured by an outer case an inch or so from the inner metal, unless, *which is always best when it can be arranged for*, one of the conductors is kept connected with the earth, and with the metal case of the electrometer also connected with the earth.

It is not at all unlikely that the fire risk rules of the Institution of Electrical Engineers will be revised, and it is only natural that they should be, considering how short has been the experience in the use of electric energy compared with that of older industries. The only improvement possible now, is to raise the standard of insulation given there.

Messrs. Goolden have also put into a convenient form the proper insulation resistance of electric-light circuits, as given by various authorities. By insulation resistance is understood the resistance not only between opposite leads, but also between each lead and earth. The rules run thus:—

Institution of Electrical Engineers' Rule.—Multiply 7,900 by volts employed, and divide by number of lamps. The result should be the insulation resistance in ohms.

Phœnix Fire Office Rule.—For installations working at 200 volts and under, divide 12·5 megohms by the number of lights. The result should be the minimum insulation resistance. Double this, if the current is alternating. High tension circuits according to circumstances.

Professor Jameson's Rule.—Multiply the volts employed by 100,000 ohms, and divide by the number of

lamps. The result should be the insulation resistance in ohms.

London Electric Supply Corporation Rule.—

Up to 25 lamps	2	megohms
,, 50 ,,	1·25	,,
,, 100 ,,	0·75	,,
,, 150 ,,	0·5	,,

Bradford Corporation Rule.—Divide 10 megohms by the number of lights. The result should be the minimum insulation resistance.

The Institution of Electrical Engineers' rule is not bad when it is considered that on a station supplying 200,000 lamps of 8 c.-p. each the total house leakage would be less than 25 amperes.

If a leakage were to exist in the house mains, when all lamps and apparatus are turned off, there would be due to this cause a continual leakage from the primary mains through the transformer or transformers, when these exist; and probably the leakage in the secondary circuit would be so small that the house meter would not register it. When the supply is of the direct-current type, loss by leakage in the house will be drawn from the street mains. If such leakages existed in a great number of houses, not only would the Supply Company suffer pecuniary loss, but a large amount of power, beyond that required to light the district, would be needed to supply the waste. For this reason, Supply Companies refuse to connect their systems with any house, unless the insulation within it is proved to be satisfactory and in accordance with their standards. The refusal to supply any house in consequence of undue leakage may appear a hardship to the owner; but, in reality, it is to his advantage, because bad insulation

is a source of danger, and he, therefore, becomes apprised of its existence and is obliged to remove it before obtaining the current. It must also be remembered that the possibility of a fire in the houses adjoining his own, due to bad wiring and fittings, is likewise averted by this system of compulsory testing. It should further be pointed out that, if bad insulation exists in adjoining houses, any house whose system is insulated runs the risk of danger, in the event of the insulation breaking down. If it could be guaranteed that leakage would, in every instance, be confined to one main, there would be little to fear; but, of course, this cannot be done. Many suggestions have been put forward for eliminating the danger, as far as possible. By some it has been suggested that one of the mains should be earthed in every house; by others, that one of the mains of the Public Supply Company should be earthed. When the public supply is off a 3-wire system, the main, which it is said should be earthed, is the middle one. It is probable that every Public Supply Company will sooner or later adopt the 3-wire system, or one on a somewhat similar principle. There can be no doubt that, theoretically, the earthing of the middle wire is the right thing to do, and that every house should have the insulation as perfect as it can be obtained. One difficulty has to be encountered with this system. If many houses have leakages on the opposite main, or if one or both of the companies' outside mains leak, there will be a considerable flow of current between the positive and negative conductors through the earth, which would form no more and no less than a partial or complete short circuit, and which would, in the event of such leakage being very considerable, result in the fuses at the central station breaking;

and the whole district, supplied from these mains, would be plunged into darkness. In fact, at the present moment, no proposal has been put forward, which approaches anything like perfection, for guarding against the danger which may arise in case of leakage; and experience goes to show that perfect insulation is an impossibility in those cases where electric energy is used over large areas. The compromise, which can be made, is the following: to earth the middle wire of a 3-wire system, or of a 2-wire system, each main successively once every 24 hours, during daylight, for a short period, say of half an hour. The result of this action would be that the fuses in all houses, in which a dangerous leakage might exist, would be melted, and the inmates would immediately have notice that something had gone wrong. If the want of insulation lay with the company's mains, it could be measured with the greatest ease and put right without delay. Also, if the insulation was so faulty that the main fuse at the central station cut the circuit, it would occur in daylight and no harm result.

The slight leakage, which occurs in every house in a district, when summed up, is one of the greatest difficulties which the Public Supply Companies have to contend with. When it is remembered that the Companies mains themselves leak to some extent, it becomes practically impossible to localise any fault with certainty at the central station, unless the fault prove to be of a very serious nature. If it were possible to insulate the street mains perfectly, the advantage to the Supply Company would be enormous. An effort in this direction is being made in the City of London by the employment of an oil insulation between the lead covering and the outside

insulation of the cable and at the joint-boxes. Mr. David Cook, the engineer and manager of the City of London Electric Lighting Company, is devising a very neat method for effecting this. Whether the attempt will meet with success has yet to be seen; but should the anticipated results not come about, the insulation will be no worse than it was before, and no money will have been wasted. The system employed for the distribution of electric energy in the City of London consists in the division of the district into twenty-two areas, each area having a sub-station containing transformers. The primaries are led from the works to the sub-stations, and from the latter the distribution is made on the 3-wire system at a low potential. Apart from economy and many other conveniences, there is one matter of great importance, namely, that connections may be made at all times without cutting off the current. The sub-stations can assist one another so far as the primaries are concerned, but the secondary circuits are distinct. Many persons have wondered why the secondaries should not be capable of inter-connection; the answer is that the leakage in the various houses would create considerable trouble, if two or more districts were connected together.

However good the insulation of the conductors of the circuit may be, as soon as the switches and fittings are added it is found that the insulation falls considerably. In new buildings and in damp places much difficulty is often experienced. To surmount these troubles the following precautions are essential. All fittings, whether switches, ceiling, wall-plates, or otherwise, should have placed behind them dry wooden blocks shellac-varnished, or plates of ebonite; and the screws which pass through

a fitting, to connect it to the wall or ceiling, should be perfectly insulated from the electric circuit.

It is extraordinary how in some cases the worst possible class of work appears to answer just as well as the best and most expensive which can be devised. The fact is that in old houses which are thoroughly dry, and in other dry situations, almost any insulation will do. Even cotton-covered wires without any rubber, or other insulating material, seems to answer, even when such wires may be twisted together. For this reason there is probably a large number of badly wired buildings, since contractors have taken advantage of the circumstances mentioned and have tendered one against the other; the owners having selected the lowest tender. This is a practice exceedingly dangerous, as may be gathered from what has been stated in previous pages.

As the meaning of a short circuit is not clear to everybody, an example may be given to explain its importance and danger. Take the case of a 100-volt current, supplying a 16 c.-p. lamp which takes 0·6 ampere, and let the leads to the lamp have a resistance of 1 ohm (ohm is the standard unit of resistance). Now such a lamp has a filament with a resistance of 170 ohms approximately, so that when lighted the passage of the current is opposed by 171 ohms, and this obstructive resistance allows only 0·6 ampere to pass. It is clear that, if the two wires leading to the lamp touch at any point so as to permit the current to pass from one wire to the other before it reaches the lamp, the latter is cut out of the circuit, and 170 ohms are removed, for the current will take the course of least resistance; therefore 170 times more current would flow, burning up the wires, since they are not large enough for such a heavy current,

doing great mischief to the cells (when present) and possibly to the dynamo, if specific precautions are not taken. These safeguards consist in cut-outs, which break the circuit the moment the current exceeds a certain value. Every branch from the mains and secondary mains and every twin wire should have a safeguard, and in private houses the mains should possess them as well. It is advisable to place all cut-outs, often called safety junctions, within easy reach, and to so construct them that the circuit can easily be re-established by resetting or inserting a new fuse without having recourse to tools.

It is very important in all cases that switch handles and switch covers, when metallic, should be thoroughly insulated from all internal portions which may carry the current.

A very interesting paper was read on March 27, 1890, before the Institution of Electrical Engineers, by Mr. Newman Lawrence and Dr. A. Harries, on "Alternating *v.* Continuous Currents in Relation to the Human Body." Two currents were employed, one alternate and one direct, and both having the same pressure; the alternations in the former being in number about equal to those employed by Supply Companies. It was then shown that the sensitiveness of the human body to the passage of the current was about forty times less for the alternate than for the direct. Assuming the figures given in that paper to be correct, there can be no doubt whatever that an alternate current of 100 volts, suitably applied to the human body, may prove a death current; whereas a direct current of 600 volts does no harm at all, producing merely an unpleasant sensation. Experiments were performed upon some of the audience on

the evening mentioned, and the results certainly bore out the statements contained in the paper.

In practice a direct current exceeding 300 volts is very unpleasant, particularly if any soft part of the skin, such as that at the back of the hand, be placed in contact with the conductors. 150 volts alternate current is still more unpleasant. Pressure beyond that is, in both cases, very painful to most persons, more especially if the skin is moist.

At all times slight shocks given unexpectedly may produce dangerous results, although not strictly due to an electrical cause. The receiving of a slight shock in so sudden a manner makes a person start: the result, if he is standing on a chair or on a ladder, may be a fall; and, if he has a weak heart, the consequences may be more serious. It is therefore all important that every piece of apparatus on a circuit intended to be handled should be insulated from those parts which carry the current; and when any operations are necessary which require the conducting portions of the circuit to be touched, the current should be turned off by means of a D.P. switch. Individuals vary enormously as to the pressure of a current they can withstand without their suffering discomfort. To those who habitually have damp hands the smallest voltages appear to produce an unpleasant feeling, if not actual pain. On the other hand, a dry skin may, without discomfort, come in contact with conductors carrying currents having voltages which would make other persons shudder even to think of. The writer, for instance, can barely perceive a 100-volt alternate current when the conductors are touched by the fingers; whereas his engine-driver is unable to touch any conductor carrying a 100-volt direct current without

experiencing intense pain. It is therefore impossible to lay down any general law on the question, " How various currents affect different individuals," seeing that the difference between them is so wide.

When the alternations of a current are exceedingly rapid, they do not appear to pierce the skin to any depth, and currents of exceedingly dangerous voltage may, under ordinary conditions, pass through or sooner *over* the body with impunity. It must be always remembered that, when the alternations are exceedingly rapid, say from a million upwards per minute, and the pressure very high, say 100,000 volts, the quantity of current must be very small indeed, unless a large amount of horse-power has been absorbed in the first instance. Up to the present time there has been great difficulty in making apparatus to produce a considerable quantity of current of this nature.

The author has recently been extending these experiments. It is very difficult to foresee how such experiments will terminate; indeed, when making investigations in a new direction, the experimenter should simply investigate what he is dealing with at the time, without prejudicing his mind as to ultimate results. Who would have thought that, when Faraday discovered induced currents, the result would be the lighting-up, by electric energy, of the cities of the world, and the transmission of power, to almost any distance, by means of a wire!

It is not impossible that further investigations and developments of the nature of high frequency and high potential currents may open up the prospect of increasing electrical efficiency from the practical point of view, and of dispensing with the use of wires altogether in con-

ducting electric energy from point to point. These are speculations which may be realised in the present century, or may require thousands of years to make them accomplished facts. No scientific man doubts that such results will come about, but when, it is impossible for anyone to say.

The question of protection from fire, security to property, and safety to life due to high potential currents, though more particularly treated in this chapter, must of necessity run throughout this volume in dealing with installation work.

Here and there the writer may expose himself to the charge of repetition to no purpose beyond extending the number of pages. This, however, is not the object; any repetitions are simply intended to lay particular stress on certain points, and to avoid the necessity for the reader to refer back in the volume.

Some writers speak of "alternating currents," others of "alternate currents." Life being short for the busy man, the writer has adopted the latter expression.

Again, some speak of the "electrical engineer," others say "electric engineer." The "Institution" would lead us to suppose the first designation is correct. Neither designation, however, is logical. The engineer is neither *electrical* nor *electric*.

The best way is to consider that a word is *understood* (as classics would say), and this word is "energy." The engineer should be called an "electric energy engineer," and for short an "electric engineer."

CHAPTER II.

CONDUCTORS.

THE word conductors covers a very large field. It is well to mention this at starting, otherwise much that will be spoken of may be regarded as having nothing to do with the subject.

Conductors include not only mains, but the wiring of the engine-house and the wiring of the house; also the insertion of all apparatus should probably come under this head.

Conductors may also be considered to include the various systems by which electric energy may be distributed and utilised, so that, when viewed in these lights, the subject will be seen to be a wide one. It must again be pointed out that this book is intended not as an elementary work, but as a general reference book for those who already have some knowledge of the question on which it treats. Therefore, while dealing with various matters, whether in this chapter or in succeeding ones, care will be taken by the writer to avoid excessive detail, which would only embarrass, if it did not confuse, those readers for whose guidance this work has been prepared.

It is best to obtain highly insulated wire, braided on the outside, for small as well as large leads. The wire should have ninety-six to ninety-eight per cent. of copper in its constitution. The section chosen ought to be pro-

portional to the current it has to carry, and always large enough to take safely twice or three times the intended maximum current. A thousand amperes to a square inch of copper is generally considered well within the margin of safety. For small wires two or three thousand amperes per square inch may be passed; but this is not recommended. On the other hand, for very large cables, a thousand amperes to the square inch of section is too large a current, especially when they are cased in, since the surface for radiation is too small and they are excluded from a free current of air. The insulation should consist of cotton, next to the wire, overlaid with separate coatings of pure and vulcanised rubber, and braided on the outside. When specially high insulation is required, many servings of the rubbers are given, with cotton between each, and sometimes tarred tape is wound between some of the coatings. The chief object in having the cotton close to the cable is to prevent the rubber compounds entering between the strands of copper wire, which considerably increases the time required in making joints and connections, on account of the large amount of cleaning necessary to remove the rubber adhering to the wires. Many makers tin the wire of the cables to facilitate the soldering of the joints, and to prevent the vulcanised rubber from acting prejudicially upon the copper when in contact with it. In many samples of cable, which have come under the notice of the author, the tinned wire has parted by corrosion, in damp as well as in dry situations. This, he concludes, must be due to the tinning process, since it has occurred in no single instance with untinned wire. Pure rubber is most durable in damp situations, and the vulcanised in dry. Consequently, if the cables are coated with both these

substances, the double advantage exists. Under no circumstances should gutta percha be employed, for this is a most perishable article unless kept under water. It is always advisable to have a cotton covering when vulcanised rubber is employed, in order to protect the copper from being attacked. If the insulating material is vulcanised rubber and the vulcanising process has been perfectly carried out—which is not always the case—it will stand equally well in dry and in damp situations. In samples of cable sometimes the copper is found to be soft, and in other cases hard. By preference the soft qualities should be selected. When the metal is hard, the wire has been very "hard drawn," or else too much alloyed ; in any case, the wire is not so pliable and there is a possibility of its breaking, when being bent round the corners. Paper insulation will be referred to directly.

Lead-covered wire should be avoided on account of the difficulty in making secure joints with it. Also, if electrical communication should exist between the outer covering of lead and the core, an enormous "earth" surface is at once given ; and it is very difficult to obtain this class of cable with perfect insulation when the coverings under the lead are very thin, because in the process of drawing the lead over the cable, small minute cavities are apt to be produced in the insulation. Lead-covered cable can now be produced with a covering as thick as an ordinary lead pipe, and with exceedingly good insulation between the metal coating and the core. For underground work, for damp situations, and in other special circumstances, this class of wire is invaluable. The joints have to be made with great care for the reason mentioned in the last chapter; but in any case they must not be employed where rats are likely to have access to them, unless a

further protection be given, for these animals are well known to gnaw lead-piping.

The concentric cable is coming largely into use. It occupies less space and is cheaper than any other kind, since less weight of insulation is employed in such a class of cable than if it had been in two cables. Insufficient attention has been given to the thickness of insulation which should exist between the metallic outside covering and the layer of cable nearest to it. The tension between this cable and earth must be the same as between the two conductors, if an earth leakage should exist upon the inner conductor. It might be thought that, since the inner conductor is completely protected, the remark just made is superfluous; but it must be remembered that this inner conductor must come to the surface on many occasions, for it has to be connected with apparatus at two or more points, and it is at these places where leakage might, and probably would, occur. The insulation, therefore, between the two conductors within the cable should have the same thickness as between the outer covering and the metallic one. When a network is laid on the 3-wire system, it is possible for the tension between the protecting metal coating and the outer conductor to be double the tension required in the houses; in which case the outer insulation should be thicker. If the system employed is the higher multiple-wire system, the insulation must have a still higher resistance. Concentric cables are made for the 3-wire system, *i.e.* an inner core and two cylinders of wire, or ribbon, placed concentrically around it with insulation between each conductor, as well as an outer insulation, which latter may or may not be protected by metal. The outer conductor should be the

"middle or equalising cable," in order to reduce the difference of potential between the cable and earth. The lead covering is sometimes replaced by twisted wire, and sometimes by an iron tube. The iron tube is employed for the Deptford mains. These latter mains are made up not of stranded wire, but of copper tubes, since it has been shown by Lord Kelvin and Professor Hughes that alternate currents travel only along the outside, and to a certain depth, of a conductor, so that no advantage would be gained by making them solid. The distance to which an alternating current penetrates a conductor depends on the rapidity of its alternations. The depth of penetration is very small for a high frequency, so that to obtain a sufficient area of copper to conduct the current, large tubes have to be employed. The penetration is considerable with the frequencies selected by Supply Companies, which generally are about 100 per second. With most of the insulating substances which have been used hitherto there is always an element of danger existing, when the conductors are heavy, on account of the possibility of the copper sinking in the insulation, or, as it is generally termed, decentralisation, *i.e.* becoming axially eccentric by reason of its weight; which may end in the copper reaching the surface of the insulation. This danger exists to a greater extent when the section given in the conductors is barely large enough for the current to be carried, since by the heat generated the decentralising operation is accelerated through the insulation being softened. The only insulation the author is aware of that appears to meet these objections is the paper insulation, which is, at present, largely coming into use. This material consists of paper or paper pulp and bitu-

minous compounds, mixed together. An exceedingly good insulator it is, and very hard. In some cases the copper is left bare and is carried in metal troughs on porcelain saddles or insulators; the air in this event being the insulating material. Some authorities prefer this method, but, on the whole, there is a far larger number of applicants for well-insulated cable of the ordinary kind.

All wires and cables (except concentric) should be so laid that a small distance intervenes between them. The circuit should always be complete, in order that the current may be everywhere carried by insulated wires. Hence measures must be taken not only against the possibility of short circuit, but also against damp, which causes leakage, and injures, first the insulation, and then the wire. Cables can be obtained which may be laid in water, but their expense is considerable. Much trouble is saved in tracing wires if the positive leads are red, and the negative black. So largely is the advantage recognised that manufacturers make cables in these two distinctive colours. Sometimes with large leads an outside braiding or covering is varied in pattern for the sake of distinction.

The best way to lay all cables and wires is in wooden slips, grooved with as many channels as there are wires to be run; or with two grooves, each containing one or more leads of the same polarity. The front is then covered with thin wood, which is screwed on, to permit of easy removal at any time. Care must be taken that these screws enter the wood clear of the wires. Saddles of leather, made from old belting, answer well to keep the wires in position. In damp places, such as cellars, the wood casing should have a coating of pitch before the wires are fixed and should not be

placed directly on the wall, but blocked out, say, half an inch. The wires themselves, when laid, may receive a coating of the same substance. The covering strip of wood is, in damp situations, best fixed, not close, but a quarter of an inch away from the channelled wood, so as to permit a current of air to pass. Outside mains may be carried in waterproof pipes laid in the ground, which are best made of ordinary cast or wrought iron

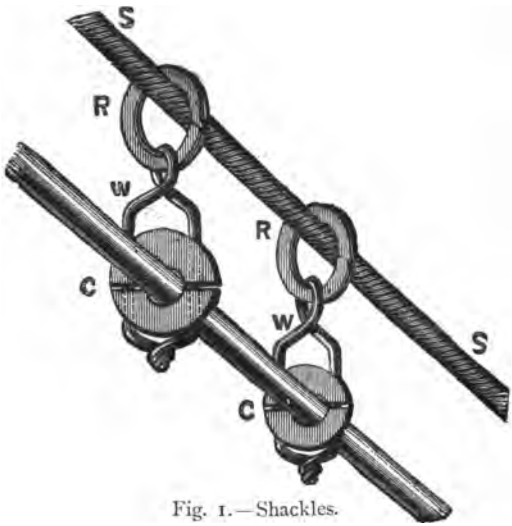


Fig. 1.—Shackles.

S, S represents the supporting wire. C, C, the conductor. R, R, rings on S, S. And W, W, the supporting portions which hold the cable.

gas tubing, for this secures the mains from damage likely to occur, should the ground require to be opened for any purpose. When mains have to be laid outside the precincts of a house, it is always advisable to resort to underground work, in order to prevent the possibility of mischievous persons or burglars tampering with the cables. When outside mains are laid overhead with long spans, it is desirable to support their weight by a strong

stretched wire made of steel, iron, phosphor bronze, or some other suitable metal, preferably by one which does not corrode. The suspension is by means of special shackles, as shown in Fig. 1.

Other kinds are made: in some types porcelain only is employed. When very good insulation is required, especially in cases of overhead wires, the fluid insulator, made by Messrs. Johnson & Phillips, should be used. This insulator is shown in Fig. 2, partly in section. Oil is the liquid used, and a special form of filler is employed.

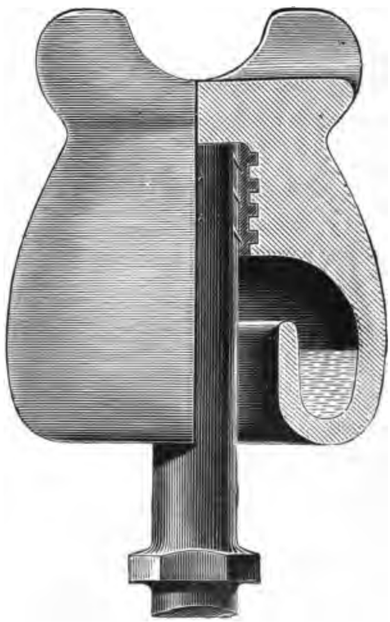


Fig. 2.—Oil Insulator.

It should always be remembered that in underground and in damp situations cast iron is more durable than wrought. For this difference many reasons have been suggested. Very probably the following explanation is near the truth, apart from any chemical considerations which may enter into the case. Ordinary observers must have noticed that wrought iron rusts in scales, which separate, and offer a fresh surface below to rust in its turn, and so on. The process of oxidisation with wrought iron may, therefore, be

described as a succession of layers of rust, thrown off one after another. With cast iron, the rust is of a powdery nature, and is more adherent. The oxidised metal occupies more space than the original metal, so that cast iron covered with rust is in a measure protected from oxidising agencies until the coating is displaced by some outside action.

It might be asked, Why should copper be selected for the conductors, in preference to cheaper materials? The reason is that copper is a very good conductor, and does not corrode under the conditions which govern its employment in electrical work. Were iron to be used, the conductors, on account of its great resistance, would be of enormous size; and this would equally apply to the various metals that are cheaper than copper.

Joints should be avoided in damp places, and in all cases they should be well made, perfectly insulated, taped, and rendered waterproof with one of the many good compounds sold for this purpose; of which india-rubber preparations, and the well-known Chatterton's compound are among the best. In many cases the rubber of the joint may be vulcanised, but this must be done with an apparatus specially adapted for the purpose and by a man accustomed to the process.

Too much stress cannot be laid on the necessity for making the joints thoroughly. Joints are an endless source of trouble, unless made mechanically and electrically in all respects as good as the conductor itself. Resin is commonly in use in this country for a flux, acid for making joints being regarded with disfavour, and rightly so. Since the success of an electric installation depends more on the efficient manner in which the joints in the conductors are made than is generally sup-

posed, it may be of advantage to say more on this subject. At a badly-made joint the wire or cable soon corrodes, and the circuit thereupon becomes broken at this point. Apart from the inconvenience that current will not flow past the severance, a source of danger is introduced by the possibility of a small arc being set up at the fracture; also damp is apt to creep along the conductors, and to cause considerable injury.

When the house is supplied from a public company, the wiring is tested for leakage. One or two bad joints may give a sufficient leakage indication for the company to refuse to connect up with their mains. This refusal frequently causes great annoyance to the householder, for, apart from his inability to obtain the light he intended to employ, it often necessitates pulling up floors and damaging decorations, in order to ascertain where the faults exist. To the author's knowledge, in more than one instance a house has had to be re-wired completely afresh, because it was impossible to discover all the joints at which leakages occurred, as they were too numerous. Good jointing, therefore, is a necessity when the current is to be obtained from a public company, as well as for the safety of the inmates.

It is strongly recommended that all joints should, as far as possible, be placed close together in groups, though this method will, probably, require a larger quantity of wire to be used. In this manner the joints, say for each room, may be collected together to one point and there be boxed in, thus forming a joint-box. When anything goes wrong with the conductors, the first points to be examined are the joints, as they may have become corroded. Instead of having to search in every conceivable place in order to make the examination, it will be merely necessary to look into the joint-boxes.

Having suggested a principle for their position, the method of making the joints may be briefly explained. First consider the uniting of wires, size of No. 16, S.W.G. and smaller, which may include very small stranded cables. Remove the insulation about an inch and a half off the ends to be joined; then bend each end of the wire, midway of the cleared part, to a right angle; hook the two together, hold them with a pair of pliers at the place of crossing, then take one end and twist it round and round the unbent part of the wire; now hold the twisted-up portion with the pliers, and repeat the process with the other bent end, but twisting in the opposite direction. If this be done correctly, the pieces which were turned up into a hook will now each encircle the opposite wire and not its own, and should appear like a long screw. For tightening the twists, two pairs of pliers are required, one to hold and the other to twist with, in order to draw the screwed coil tight upon the wire, which now forms a core, or may itself have become twisted in the process. It has been assumed that the ends, after removing the insulation, have been thoroughly scraped. Some powdered resin is now placed upon the joint just made, and with a soldering bit, solder is applied; then the junction may be regarded as completed, so far as the metallic portion is concerned. This is now to be insulated, and with very great care. The insulation upon the wire consists of several independent coverings. The best plan is to take off the outer covering for small wires, about an inch back on each side from the bared metallic portion; then to remove the second covering half an inch back in the same way, and the third covering a quarter of an inch. In this manner the insulation is stepped

backwards on each side from the joint. The bared part is now encircled with india-rubber strip, and is warmed with a "cool" soldering bit so as to make it adhere. This should be wrapped with tarred tape to bring the level up to the first step of the insulation which has been cleared. Thereupon apply a coating of india-rubber solution or of Chatterton's compound. Then successive coverings of tape and servings of compound should be given till the joint is covered to the same level, or slightly above that, of the general insulation of the conductor; each covering overlapping the insulation of the wire or cable.

If these instructions are faithfully carried out, the joint ought to be stronger metallically and the insulation no worse than any other portion of the wire. For heavy conductors the insulation of the joint is carried out in the same way, only that the stepping of the coverings should be made longer.

Evidently, if the metallic connection at the joint has no less a section than that of the cable itself, this is sufficient. It is, therefore, not essential in the case of stranded wires that the two bared ends shall be twisted one upon the other; for in this event the section at this point will be double that of the cable, and the joint itself large and clumsy.

The methods for joining stranded cables of 7, 14, or 19 wires may be mentioned, since they are the kinds most commonly in use. In joining these three classes of cable it is usual to remove the cores and joint the exterior wires only. In the case of the 7-strand cable the core consists of one wire; in the 14, four wires; and in the 19, seven wires. How to join a 19-strand cable, this size presenting greater difficulties than the smaller

ones, will be described, and the method is the same for other sizes. Bare the end of one cable for a length of six inches. Bend back the outer ring of wires at right angles with the cable axis, the bending points being four inches from the end. Cut off with the hack-saw, chisel, or nippers, the central portion of the cable at a point where the other wires are turned back. At this stage the end view will have the appearance of a centre, with twelve radiating wires like spokes of a wheel. There will also remain a plain bared part of the cable two inches in length. The other cable to be joined is treated in a similar way. Each wire is carefully cleaned, so that it may take the solder. The cables are now butted, the cores being placed in contact with each other and in such a position that the bent-up wires of the one cable alternate with those of the other. These are now bent down straight again, so that the exterior wires of the one cable lie upon the bared portion of the other. Two pairs of gas pliers are now employed to complete the joint; one pair being used to hold the wires down on the one cable, whilst the other pair is closed and given a rotary action in one direction, which twists the wires, just bent down, spirally around the portion of the cable on which they lie. The same process is performed upon the other side, which was held during the last operation, but in this case twisting the opposite way. The twisting operation is repeated afresh, turning both the gas pliers at the same time, which draws the joint up perfectly tight. If this process is carried out in a workmanlike manner, the appearance of the joint should be absolutely symmetrical and neat. Soldering must now be resorted to, a good heat being required for the metal to flow well

between the wires. Then the joint is insulated, and this place should never require looking to again. The time occupied to make a $\frac{19}{16}$ joint is about an hour. Many a workman can do it in less time, but one hour is by no means too long to produce a satisfactory result.

The following (see Fig. 3) are a few illustrations of joints. There are shown a bare cable joint, a joint covered with the first layers of insulation for a straight and T form.

There are a few general points connected with cables and wires, a knowledge of which is found convenient in practice, and for instructing the workmen, although from a scientific point of view they have no value. It has been already recommended that the positive and negative leads should be of different colours. Now it may further be pointed out that, in the case of twin wires, the covering of each wire should be of a different colour or a different pattern, so that a distinction can be recognised without testing or trying to trace the wires, for mistakes often occur when such attempts are made. Frequently the distinction is made not in the outside covering, but by a difference of colour in one of the under-coverings; but an exterior distinction is undoubtedly the best.

A No. 16 S.W.G. may be considered to carry with safety, for its limit, 3 amperes; but it is better to pass not exceeding 2 amperes, or say current for six 100-volt 8 c.-p. lamps.

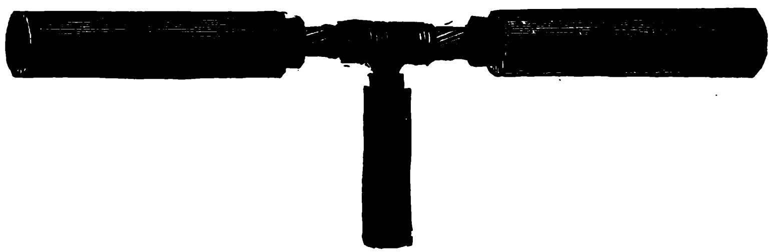
A No. 18 S.W.G. may convey current for four such lamps, a No. 20 for two.

For distinguishing between a 7, 14, and 19-strand cable, without attempting to count the wires, the following way is the simplest. In a 7-strand, one wire is central, with six others closely packed around it: in appearance a small rosette. In a 14-strand cable, the centre

consists of four wires. A 19-strand conductor has the appearance of a 7-strand, with another row of wires around it. Workmen frequently make a mistake

Method of jointing straight conductor.

Joint covered with tape.



T-joint.

T-joint taped.

Fig. 3.—Illustrations Showing Method of Making and Insulating Joints on Electric Light Cables.

between cables having 14 and 19 wires, but by remembering the above facts they can easily distinguish one

from the other; *i.e.* the 19-strand has a central wire which is absent in the 14-strand.

Many workmen are at a loss to know the best way to cut a cable. The three easiest methods may be indicated:—

1. By the employment of very heavy nippers, generally sold under the name of "giant nippers."

2. When cutting pliers are not present, a block of wood may be placed under the cable at the point where it is to be cut, and with a mallet, an ordinary wood chisel may be driven through the cable. This makes a nice clean cut.

3. With a carpenter's tenon-saw or with a hack-saw.

The best hack-saws in existence are the American ones, which may now be obtained at all tool-shops. Their virtues may be thus summarised: the frames are strong and easily adjustable, and the saw blades are soft, with the exception of the teeth, which permits of the saw doing its work without any risk of snapping; hitherto a constant source of great annoyance. These saws serve for cutting iron pipe or any other hard substance. By their use the author saves many pounds in the course of every year.

A common practice is to burn the insulation off the ends of the wire, instead of clearing it off with a knife. This practice is not good, for the heat is conducted along the wire and is apt to injure or melt the insulation where it should remain perfect. The surest and quickest way for trimming the ends of small wires is to lay upon a flat surface the portion to be cleared, and to cut off the insulation with a sharp knife, by an outward stroke, and in a direction away from the operator. The first cut will remove nearly half the insulation, exposing the wire, which can be pulled out of the other half. This portion of the insulation is now cut off in such a way that the

knife edge does not turn towards the wire. This method averts the injury, usually done in the common practice by passing the knife around the wire, which so frequently results in a fracture.

To clean the ends of the cables, the knife may be passed around the conductor, if proper care be used. A slit is then made from this circular incision to the end in the direction of its length. The loosened insulation can now, with the fingers, be removed in a piece. In order to clean the wires the common practice is to scrape with the sharp edge of a knife, which, by this process, is rapidly blunted. It will be found more convenient to scrape with the back of the knife, and if this is not found sharp enough for the purpose, it is only necessary to grind the back, keeping it with a square surface as before. The right angle scraping section is favourable for the operation. Special tools from time to time make their appearance for cleaning the ends of wire, but there is no practical advantage to be gained by their use.

It is always advisable to pass flexible wires over wooden, ebonite, or vulcanised fibre pulleys, when these are necessary. They are much superior to those made of metal, and a frequent source of short circuit is avoided.

Joints and cut ends of wires and cables should not, without protection, be left in this state in damp situations, since moisture will probably enter and pass along the core. It is, therefore, desirable to insulate the joints temporarily and to seal exposed ends till they can be finally dealt with.

When lamps are used outside, the socket form is perhaps the best, since the ends of the conductors leading to the lamps are protected If the lamps are

removed for any considerable portion of the year, the sockets should be filled with blanks.

Where much vibration occurs, loop lamps may be used advantageously. More than one case has been reported to the author, of great heat being generated at the lamp sockets, due to bad contact caused by the vibration of heavy traffic, which in one instance produced a fire, but as the fact was discovered immediately, no damage was done. The author has failed to discover any insulation of an absolutely lasting character. Some of the very best insulated wires which can be purchased have shown deterioration when exposed to damp, as well as when put in dry places; and this fact renders it the more necessary to be particular in laying the wires in a careful manner. In damp places the insulation, becoming injured, drops off; in dry places it becomes hard and brittle.

No opinion can be formed at the present moment as to the lasting character of paper insulation, and of certain other materials which have recently been brought into use for the purpose. Time alone can settle the question. Perfectly vulcanised rubber is exceedingly lasting, but then comes the difficulty of obtaining this material in a perfect condition. If any free sulphur remains after the process of vulcanising is completed, the lasting properties sought are not present.

After many experiments as to the best method of laying wires out of doors and in damp cellars, the following has been adopted as having proved satisfactory and cheaper than other ways which might be used.

A wooden casing is employed, as usual, well pitched inside and out; and, instead of being fixed close to the wall, about an inch of space is allowed to intervene

by means of wooden blocks. Any moisture running down the wall consequently passes behind the casing. The cables and wires are inserted as usual, and the cover, also pitched, is put on with a piece of zinc in front of it, the lower edge of the zinc projecting about half an inch below the woodwork, which prevents water being drawn up between the zinc and the wood. Another piece of zinc covers the back of the casing, also projecting half an inch below it, and is bent over the top towards the front at such an angle as to be in appearance a lean-to roof, the end of the slope being in advance of the casing. In this manner the casing can be kept perfectly dry.

When the leads are carried in damp situations, it may be advisable to have them of rather smaller section than the nature of the circumstances would strictly call for. By this means, when a current is flowing, the leads would be slightly warmed and thereby the insulation would be kept dry. When acting on this suggestion care should be taken that the heating is only very limited in degree.

The fall of E.M.F. between any two points of a circuit is equal to the resistance in ohms between the two points multiplied by the current.

Mr. Massey has kindly supplied the author with a convenient table which he uses, showing the number of 100-volt 16 c.-p. lamps, which the ordinarily sized wires will carry as a maximum with a fall of one volt:—

Size of Conductor S.W.G.	Carries current for 100-volt lamps 16 c.-p.
3/22	3
7/22	8
19/22	20
19/19	45
19/16	100

Under these conditions there is a fall of one volt in a distance of 60 feet (viz. 120 feet of wire).

The best way to make an earth for testing, or for safety devices, is to solder the testing wire to a water-pipe, and not to a gaspipe.

There is a prevailing idea that a leakage will cause a fire. This is not the case except under peculiar circumstances, such as when a nail driven through the casing pierces the insulation and becomes red-hot, which might occur in the event of a large leakage on the opposite line. At the same time leakages should be guarded against, since they eventually lead to danger by the destruction of joints, and frequently of the cable itself. If, when the wiring is in bad order, the fuses fail to act at the proper moment, the leads may become overheated.

For a certain class of problems the author has worked out the following formulæ. Engineers generally calculate by rule-of-thumb, either by making trials or by reference to tables; but for careful work approximations are not always sufficient, and the methods now employed for solving the problems about to be mentioned frequently fail when the engineer is at a loss to know how to proceed, unless his knowledge enables him to work out the matter for himself. To give an idea of some of the problems referred to, the following instances may be mentioned as samples:—

1. What resistance should be introduced to lower the electro-motive force at the lamps, two volts on a circuit employing 100 volts when 40 8 c.-p. lamps are in use?

2. It is required that a motor passing 10 amperes at 100 volts shall pass 9 amperes: what resistance should be inserted?

3. What additional resistance is necessary to reduce a 100-volt current from 20 amperes to 19?

4. In a 100-volt circuit, in which 22 amperes are flowing, to what extent will the E.M.F. be reduced by the introduction of 0·3 ohm?

All these, and hundreds of other similar problems may be solved by the following formula:—

Let R = resistance in ohms of the circuit $=\frac{E}{C}$.

„ R_1 = the resistance in ohms to be added to produce the desired effect.

„ P = the percentage of fall of E.M.F. required at the lamp.

„ $\frac{1}{p}$ = the fall of E.M.F. required at the lamps when not expressed as a percentage, but as a proportion of the total E.M.F.

„ E = the initial E.M.F.

„ E_1 = the reduced E.M.F. required.

Then if a certain percentage of fall of E.M.F. is required, the resistance to be added to the circuit is:—

$$R_1 = R\frac{P}{100-P} \qquad \text{(I.)}$$

When a fall of E.M.F., not expressed as a percentage but as a proportion of the total E.M.F., is required, the added resistance is:—

$$R_1 = R\frac{1}{p-1} \qquad \text{(II.)}$$

When a certain E.M.F. is to be reduced to a new E.M.F., the extra resistance is:—

$$R_1 = R\frac{E-E_1}{E_1} \qquad \text{(III.)}$$

Formula III. may also be employed for the inverse problem, only in this case the E_1 is the original E.M.F., and E the new one. Suppose that it is found, when the engine-house is situated at a distance from the residence, that the pressure in the latter is too low, it will then be necessary either to raise the E.M.F. at the generating station, or to increase the size of the leads therefrom; and in most cases the latter course is the only one available. From Formula III. the new resistance which these mains should have can be found.

It must be observed that the value of $R\,\frac{E - E_1}{E_1}$ in this case, will be negative in sign; which is what might naturally be expected.

Now, if r_1, r_2, r_3, &c., represent the resistances of several conductors connected in parallel, the joint resistance will be :—

$$\frac{1}{\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3}, \text{ etc.}} \qquad \text{(IV.)}$$

and if only two such conductors, r_1 and r_2, are so connected, the joint resistance will be :—

$$\frac{1}{\frac{1}{r_1} + \frac{1}{r_2}} = \frac{r_1\, r_2}{r_1 + r_2} \qquad \text{(V.)}$$

Formula V. is very useful in practice, and may be applied in the case just mentioned, where it was supposed that the resistance of the mains to the house was to be diminished. The simplest, as well as the cheapest, way to do this is to add a cable to each main in parallel. It must not be forgotten that, in speaking of the resistance of these mains, there are two leads and that R

refers not to the resistance of one lead, but to that of the two added together. It will now be shown how to obtain the proper resistance, which should be given to the cables intended to be added in parallel.

In the case given, the original resistance of the engine-house mains must be reduced by the addition of $R\frac{E-E_1}{E_1}$ which now is a negative quantity; therefore, the new resistance of these mains will be :—

$$R+R\frac{E-E_1}{E}=R\frac{E}{E_1} \quad . \quad . \quad . \text{(VI.)}$$

The new value of the resistance of the mains will also be $\frac{R\,R_1}{R+R_1}$, where R is the original resistance of the mains, and R_1 that of the cables to be added in parallel. Hence :—

$$R\frac{E}{E_1}=\frac{R\,R_1}{R+R_1} \quad . \quad . \quad . \text{(VII.)}$$

Solving Equation VII. for the value of R_1 which is required, we obtain :—

$$R_1=R\frac{E}{E_1-E} \quad . \quad . \quad . \text{(VIII.)}$$

This value for R_1 is positive, since E_1 is greater than E by hypothesis.

The value of the current flowing does not appear to enter into these calculations; it does, however, for the original value of R depended upon the current value.

Equation III. may be expressed in another way. The value of $E-E_1$ is the difference between the old and new pressures, and may be represented by D; hence Equation III. becomes :—

$$R_1=R\frac{D}{E_1}; \quad . \quad . \quad . \text{(IX.)}$$

where $\frac{D}{E_1}$ is the amount of the decrease of E.M.F. compared with the new pressure. Calling this Δ, we obtain :—

$$R_1 = R\,\Delta \quad . \quad . \quad . \quad \text{(X.)}$$

To give an example :—Let it be required to lower the E.M.F. from 100 to 98 volts, when 10 amperes are flowing. Then since $R = \frac{E}{C}$, here $R = 10$ ohms. Also :— $\Delta = \frac{2}{98} = \frac{1}{49}$; consequently, a resistance equal to $\frac{1}{49}$ of the original resistance must be added, namely, $\frac{10}{49}$ ohm, or approximately 0·2 ohm.

Equation VIII. may also be reduced to another form. If $E_1 - E$ (the difference of pressures) be represented by D_1, we obtain :—

$$R_1 = R\frac{E}{D_1} \quad . \quad . \quad . \quad \text{(XI.)}$$

If d is now put to represent the proportion which the difference of the pressures bears to the previous pressure, then $d = \frac{D_1}{E}$, and Equation XI. becomes :—

$$R_1 = R\frac{1}{d} \quad . \quad . \quad . \quad \text{(XII.)}$$

To give an instance :—Take the data in the last example, only suppose that the E.M.F. is to be raised two volts—*i.e.* from 98 to 100—then what resistance should be given to the cables to be added in parallel to those existing? Here $d = \frac{1}{49}$, hence the added cables must

have a resistance 49 times that of the original cables; that is, 490 ohms, or for each lead half this value. Once having determined what resistance should be added in series or in parallel, according to problem required to be solved, it will only be necessary to find the suitable wire or cable to be employed, and this may be found in the price lists of all cable manufacturers.

It should also be noted that, whether the results sought for are to diminish or to increase the original resistance, the new value for resistance of the mains will always be $R\frac{E}{E_1}$. The practical use of this value, in cases where the resistance has to be increased, occurs in those instances where a permanent reduction of E.M.F. is desired without placing a separate resistance. In this event smaller wiring may be introduced to obtain the required value, the original resistance having first been calculated on the data commonly employed for general installation work. It is not often that the whole of the wiring is required to be of a size to reduce the E.M.F. more than is possible, having regard to the cost; but special cases sometimes arise, and this formula gives the solution.

All mains and branches ought to be laid on a system and should start at centres. This is convenient for testing at any time, or for running new branches. Wherever a branch starts of smaller section than the main or branch whence it is derived, a safety junction should be inserted; and, if extra security is desired, these fuses may be placed in both leads.

It is desirable in some cases to duplicate cut-outs. For instance, where experiments are being conducted, in connection with motors which may by chance be sud-

denly pulled up, whereby an enormous increase in the flow of current would be produced; and in other special cases. When the direct current is employed, it is best to use a magnetic cut-out, set at a lower value than the fuse, since this cut-out will act first, and is more easily placed in circuit again. In the event of the magnetic cut-out failing, then the fuse comes into play. The same remark applies in those cases where for some reason two fuses occur successively for a lamp or any other piece of apparatus, *i.e.* the fuse which can be most easily reached should be rather smaller than the other one.

To avoid danger, in the event of leakage at any time, it is advisable that all fuses should be placed conveniently for the purpose of examination or renewal. In rooms already decorated, the wires may be laid without casings, except in places within reach, say, six or eight feet from the floor. If the wires are fixed about one inch apart above the picture-rods and under the cornice, they will then be completely out of sight. In houses wired before decoration, the casings may be laid level with the plaster or form one of the mouldings of the skirting, dado, or cornice; but the wires should always be easily accessible, and ought never to be laid in the walls or under floors, unless positively necessary.

In almost all instances, casing is desirable. The casing cover may be moulded to suit the decorations of the room; its presence therefore need not be unsightly, and, when placed in angles, its existence passes unnoticed. The objection to laying wires under floors is the possibility of the nails, which fix down the boards, passing into the casing containing the wires and

injuring the latter; also the danger arising from any water being upset over the floor entering the casing. In old houses it is all but absolutely necessary to lay the leads in this way; and, in such an event, care should be taken that the casing containing the wires is fixed at a considerable distance below the floor-boards. By such means the nails will not reach the casing. All cables laid under floors should be very much larger than the size actually required, so as to prevent the necessity of having to relay them at any future time, should more lamps be added to the installation, or should the lamps be changed for others giving a higher illuminating power.

Where leads of any kind cross iron pipes or girders and pass through floors and partitions, great care is needed in order to give proper protection to them at such places. Where wires must cross one another or pass through a floor or partition, proper precautions should be taken to keep them apart, and to prevent their approaching anything of a combustible nature. For example, in traversing wood framework, an earthenware or metal pipe to pass the wires through ought to be used. Casing may be rendered fireproof by painting the wood with asbestos paint, or with a solution of tungstate of soda. Many specimens of asbestos paint are not fireproof, so no reliance must be placed upon the paint to be used until its qualities have been proved by experiment.

When cables pass through holes in walls it is a common practice to fill the space around the cables with Portland cement. This substance is likely to injure the insulation. The best method is to use plaster of Paris and face it with Keene's cement, and further with a

coating of india-rubber in solution (benzole is a good solvent) if the place is exposed to the weather. Sometimes it is easier to apply Portland cement, and when this becomes necessary, the cables should be wrapped in rag, india-rubber sheet, or tarred tape, so that these substances may be acted upon by the cement, instead of the coverings of the cables themselves.

It may be pointed out that considerable difficulty has been found in preserving the insulation upon the leads in old houses infested with rats. There are, practically, only two ways of overcoming the difficulty. The cables must either be laid in iron tubing, or coated with some substance which may contain poison, and which shall be so distasteful to those destructive animals that they will be deterred from meddling with the cables at all. Even mice and blackbeetles are sometimes a source of annoyance, and whenever this occurs the precautions mentioned should also be applied.

In every instance a plan of the wires, with all details and positions of joints, should be made. If any wires outside the house are not underground, lightning guards should be employed; otherwise, there is danger during thunderstorms. When high E.M.F. is used, protection against danger to life may, in the majority of cases, be secured by "earthing" one of the mains; but only in such instances should this be resorted to.

In this case an earth upon the other main will cause the fuse to go and to cut the circuit. The protection to life, therefore, is only partial. The probability of an accident is comparatively remote.

A very ingenious and simple plan, devised in France, for turning a lamp on and off at two places has been published in one of the electrical journals. (See Fig. 4.)

Let A and B represent the mains, C the lamp, D and F two two-way switches placed at two points where they are required to be used; E and G are the fingers of the switches; J, K, L, and M, the contact pieces; and H and I the two leads, to complete the circuit containing the lamp, one only being in use at a time.

Now, if finger G stands on J, and finger E on L or M, the lamp will be alight, and it may be extinguished by the use of either switch, the only condition necessary for the operations of lighting and putting out the lamp being that the fingers G and E must always be on a contact-piece. This will invariably be the case if the switches have a suitable snap action.

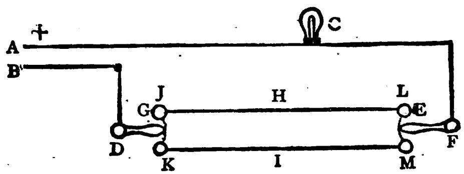


Fig. 4.—One Lamp Actuated at Two Points.

It is, therefore, evident that the lamp may be turned on or off at either switch, without the necessity of touching the other. This principle applies equally when more than one lamp is required, for the main A may be laid on the parallel system to maintain several lamps, or many of the latter may be placed in series.

This system might be so extended as to put switches at three or more places.

It is curious that, although the author did not give, in the last edition of his book, the extended method for lighting and extinguishing one lamp from many points, Mr. Massey wrote to him asking whether he knew of such a method, as he had devised one. This was in Septem-

ber 1891, about a year after the author had actually devised the method, which turned out to be identical with that suggested by Mr. Massey. A sketch (Fig. 5) is now given showing how this may be done. It is right to explain that Mr. Massey took out a patent for the method about this time, and as the author did not, in the technical sense of the word, make publication earlier, it is only fair that Mr. Massey should reap any advantage that may accrue from his independently produced device. The following is a diagram of the method, and all the connections and combinations can easily be traced. The switch fingers are drawn too short for the sake of clearness.

Lamps can be placed in series, parallel, or in some combination of the two. In all methods except the parallel system, high pressures are required. Therefore for house lighting, the parallel system is almost universal. The series methods take an im-

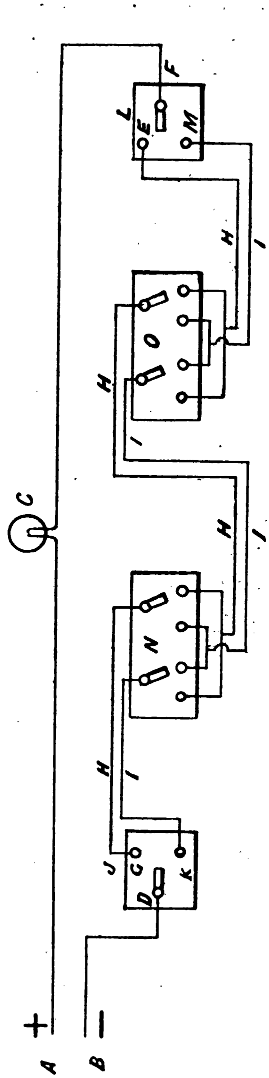


Fig. 5.—Lamp Actuated at Many Points.

portant place in certain classes of lighting, such as for factories, and for certain public uses.

To give a general idea of the parallel system, let it be assumed that twenty lamps are to be used from a dynamo. Suppose that from one dynamo terminal twenty wires start, and each wire has a similar lamp placed in its course before being returned to the other dynamo terminal, let every branch have an equal resistance. Then we have the current on leaving the dynamo dividing into twenty courses, lighting twenty lamps; all equally bright, because the resistance of each circuit being equal, equal currents traverse them. This is the parallel system, but in practice, to start all lamp circuits from a point is neither possible nor convenient; consequently long and large mains are laid, one from each terminal of the dynamo; and no connection exists between these mains except by branches connecting them, in the course of which the lamps (motors or other apparatus) are placed. The resistance of the mains is so small, as compared with that of each branch with its lamp, that the resistance of the mains between point and point, whence the branches start, may be neglected; and we return to the equivalent of the first arrangement, where all the branches were supposed to start from the dynamo. It is also evident that, when the lamps at every point are required to be equally bright, large mains become a necessity, apart from the question of carrying the current safely; and they must also be larger in proportion as the E.M.F. of the lamps is lower, since the resistance of each branch and lamp is smaller; and consequently their resistance, compared with that of the mains, has a lower ratio. Hence the higher E.M.F. required for the lamps the more equal is the light given from each lamp in all

parts of the system, even though smaller mains be used. In order to have absolutely equal light from similar lamps on every branch, it is necessary to make a series of calculations for finding the proper sections which should be given to each branch, so that the resistance of each lamp circuit measured from the dynamo terminals shall be equal. In

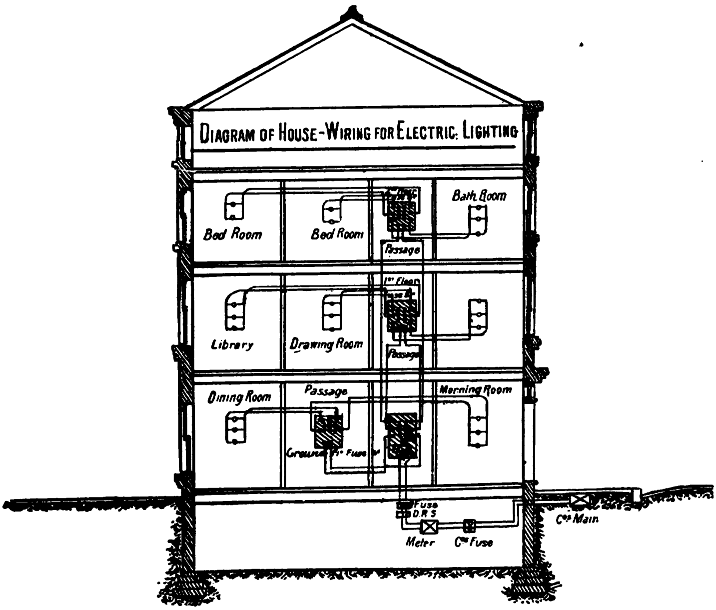


Fig. 6.—Diagram of House-wiring.

practice, however, such precision is not demanded ; for when all the conductors are laid in accordance with the rules, which have already been given, and which are further touched upon in this chapter, the difference in brilliancy of any lamp from the others would be inappreciable.

In order to present some idea of a few circuits, the

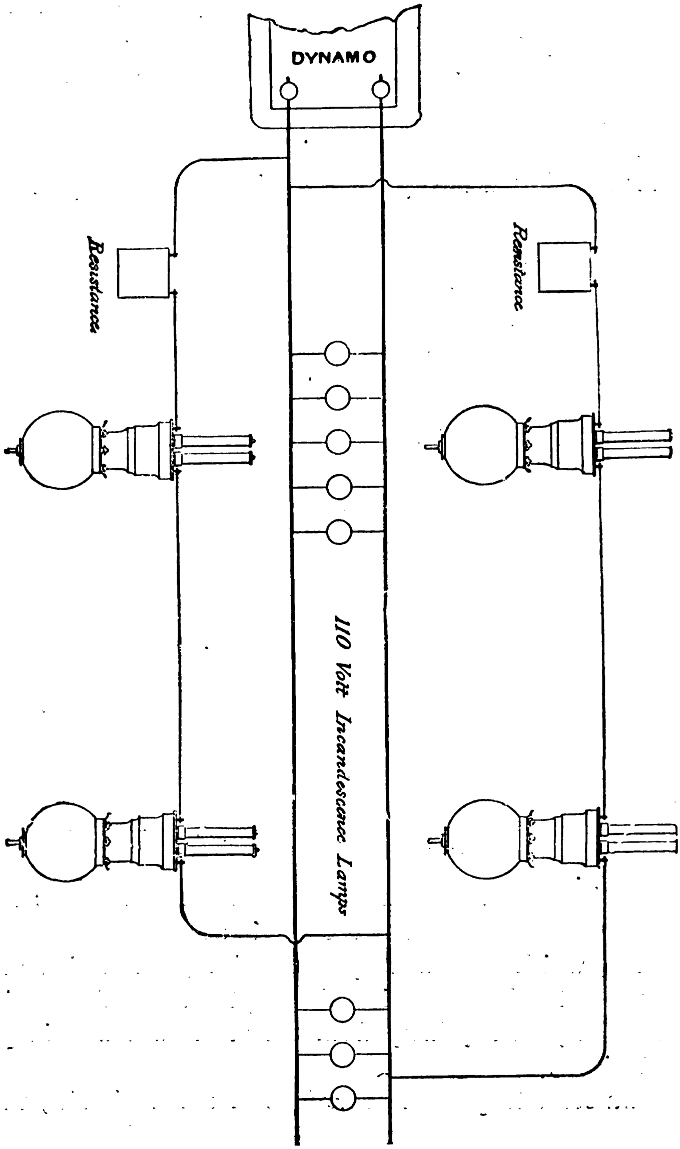


Fig 7.—Diagram of Arc and Incandescent Lamp-wiring.

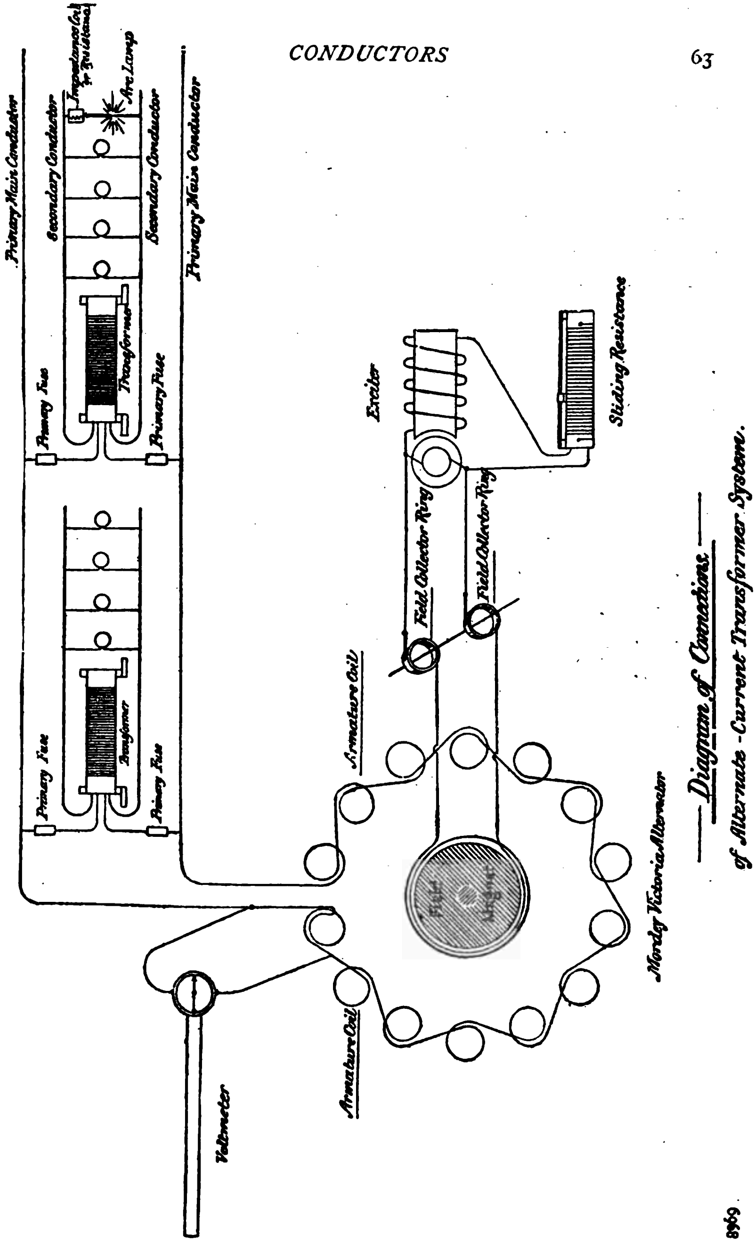


Fig. 8.—Diagram of Connections of Alternate Current Transformer System.

preceding plates are given. Fig. 6 is a diagram of the method of wiring a house off direct current mains. A very good idea of the system generally can be gathered from this sketch. The wiring of the house would be the same, were alternate currents employed; only the leads would start from a transformer in connection with the company's mains.

Fig. 7 represents a system where arc lamps and incandescent lamps are used upon the same circuit. The two resistances shown are merely employed for regulating arc lamps.

Fig. 8 is a diagrammatic representation of an alternate current installation, showing the alternator, exciter, with regulating resistance, and two centres of transformation which might be individual houses or districts.

High volt lamps blacken less than low volt ones, which is a great point in their favour; and they are quite as lasting if not overrun.

With alternate currents the lamp globes appear to blacken more quickly than with direct currents. This may be partially due to the fact that the E.M.F. is usually less constant in the alternate current systems of supply.

The tables following may prove of use as well as of interest. One gives the "fusing currents" for tin wires;

Fusing Currents for Tin Wires, Calculated from Mr. W. H. Preece's Tables. (For calculating Safety Fuse Wire.)

S.W.G.	Diameter in mils.	Fusing current	S.W.G.	Diameter in mils.	Fusing current
14	80	37·3	24	22	5·4
16	64	25·5	26	18	4·0
18	48	17·4	28	14·8	3·0
20	36	11·2	30	12·4	2·3
22	28	7·8	—	—	—

Table of Lengths of Wires of 1 *Ohm Resistance for Various Diameters, at* 15·5° *C.* (*For calculating the Length of Wire required for Resistance, Frames, &c.*)

S.W.G.	Diameter in mils.	Iron	German silver	Platinoid
		Ft.	Ft.	Ft.
6	192	576	274	198
8	160	400	190	137
10	128	256	122	88·0
12	104	169	80·5	58·1
14	80	100	47·6	34·4
16	64	64	30·5	22·0
18	48	36·1	17·1	12·4
20	36	20·2	9·64	6·96
22	28	12·3	5·85	4·22
24	22	7·56	3·60	2·6
26	18	5·06	2·41	1·74
28	14·8	3·42	1·63	1·18

Striking Distance Between a Point and a Disc. (*For Measurement of High E.M.F., Insulation, &c.*)

Inches	E.M.F. in volts	Inches	E.M.F. in volts
0·5	11,700	8	186,900
1	23,400	9	210,300
2	46,700	10	233,700
3	70,100	20	467,300
4	93,500	30	701,000
5	116,800	40	934,700
6	140,200	50	1,168,300
7	163,600	—	—

Table of Sizes, Weights, Resistances, and Working Currents of Copper Wire, 100 *per cent. Conductivity.*

Number S.W.G.	Sectional area, inch	Resistance at 65° Fahr. 1,000 yards	Per mile	Working current amperes
		Ohms	Ohms	
22	·0006	40·78	71·78	1
20	·0010	24·11	43·42	1
18	·0018	13·88	24·43	2
16	·0032	7·61	13·62	3
7/22	·0044	5·73	10·09	5
7/20	·0072	3·47	6·11	7
7/18	·0128	1·96	3·44	13
7/16	·0229	1·10	1·93	23
19/16	·0624	·40	·71	63
19/14	·0973	·26	·45	97

another shows the resistance of iron, German silver and platinoid wire; a third shows the striking distance between a point and a disc for an electric spark of different voltages; and lastly, a table giving information in regard to copper wire.

The table of striking distance is correct only if the point and disc are clean, and for direct current. The figures were compiled by the late Mr. Warren De La Rue and Mr. Hugo Müller.

The working current is calculated on the basis of 1,000 amperes per square inch of sectional area.

The resistance of copper wire increases about 0·38 per cent. for every degree Centigrade.

In wiring a house it must always be borne in mind that, when alternate currents are used, the ordinary methods of calculating the resistance are no longer true, but vary with the frequency. Professor Hughes was probably the first to call attention to this matter, and Lord Kelvin has published many papers, which contain all the necessary calculations for given data. The resistance of a circuit to alternate currents is greater than to direct. For frequencies up to 100 per second the wiring may be the same as in the case of direct currents, unless the currents are very large, since this would require copper conductors of large diameter. It is convenient to bear this in mind, because the alternate currents supplied by public companies in this country do not exceed this frequency.

The best place to put the lamp switches is upon the shutting doorpost or the wall close by. In this manner a room may be lighted before entering, the door having first been opened to obtain access to the switch. By

working upon a symmetrical plan the switch can be found in any room throughout the house; in the same way, in passages, some system of placing the switches should be followed. When "tap" switches are used, the tap vertically placed should be "on" and horizontally "off"; for this avoids doubt as to whether the circuit is cut or not in the case of worn-out lamps, broken circuits, and the like. When tumbler switches are used, symmetry would be obtained by arranging the switches so that the handles point upwards for "on" and downwards for "off." Never place the switches of a room outside, which is so often done. In an asylum this course is desirable, so that no inmate should extinguish the light to the common danger. These points settled, attention should be given to the matter of wall-connectors for portable or fixed lamps, which should be placed near all tables generally used for work, and by bedsides, where the switches may, with advantage, be painted with luminous paint.

The bases and covers of all switches are best made of incombustible material, and fixed in a safe place. It is then rare that harm is done, even if the switch be left arcing, for the metal burns away, and eventually the arc is cut by increasing its length; yet it is advisable to guard against this. The lamp will indicate whether an arc exists at the switch, for it will glow very dull, as if turned down. But it must not be supposed that the simple fact of burning dull necessarily indicates an arc, for this might be produced by other causes.

There is no simple way of turning down a lamp, although for this purpose switches, containing carbon, resistances, and other devices have been made. They have not come into general use, because the power absorbed by a lamp turned low is nearly the same as when

bright. Therefore, no economy worth mentioning is produced; and the lamps are so easy to relight that it is better to turn them off altogether. Compared with a large one, a small lamp is an economy; but in both cases the actual brightness of the filament is the same. Consequently, when full and half light are required, two lamps should be used, one or both being turned on at pleasure. It is true that a lamp burning low takes less current, but the resistance used to effect this end consumes energy.

For a night-light it is sometimes convenient to employ a lamp which is burning dull. This can be easily effected by inserting a resistance in the course of the wire. A very convenient form of resistance for this purpose is to put another lamp in series with the one in use. The two lamps may be used together to form a night-light. For instance, if upon a 100-volt circuit two 8 c.-p. 100-volt lamps are placed in series, the pressure of the current for each lamp will be only 50 volts; and the light given by the two lamps combined will be very little.

Many rules have been laid down as to the number of lamps required to light a room, but they have no practical value on account of different decorations absorbing more or less light; and when there are pictures, considerably more light is required. The quantity of light also depends a good deal on the fancy of the individual. Much depends on the positions of the lamps and the levels on which they are placed. The best and most reliable way is to take a number of good light-giving lamps, such as the kerosene duplex, which gives about the same quantity of light as a good 8 candle-power incandescent lamp, and to place them

about the room, high and low, till the desired effect is obtained. This test serves as a guide for the wiring, and fixes the positions where lamps shall be put. The most pleasant lighting is obtained by placing the lamps round the room about eighteen inches or two feet from the wall, and seven to eight feet from the floor. This method is the most economical; and in rooms to work and read in, a few more lamps may be placed so as to obtain additional light at special spots. When a room is used only for reception purposes, a better effect may be produced by placing the lamps ten feet from the floor. Fittings are better dispensed with, the lamps being simply suspended from the ceiling or from brackets by flexible twin wire; and when desired they can be obtained ground or obscured to avoid glare, or they may be toned down with silk shades. Ground or obscured lamps waste 15 or 20 per cent. of light, but it does not follow that this is a disadvantage or even waste in all cases, for the obscured globes diffuse the light much more equally, and in fact the room will be found positively lighter when such lamps are used.

The author has always pointed out the advantage of using obscured lamps, and only recently their use has been generally recognised. It is well-known that, if a candle is placed between two mirrors nearly parallel, there will be successive reflections of the candle nearly *ad infinitum* from mirror to mirror. If no absorption existed at each reflection, there would practically be no limit and the light of the candle would be multiplied to any extent. To describe this old experiment in another way, one might say that the reflected light is far greater than the original, and consequently the former plays a more important part in illuminating a room than

does the radiant itself. This rule is true, except as regards rooms where the decorations are very dark: a stupid fashion which came into vogue a few years ago, to the detriment of health and impairment of the spirits of the inmates. Fortunately this folly is passing away.

Many years ago the author pointed out that the reflected light in a room was more important than the source of light itself, and in consequence obscured lamps were more advantageous than clear ones. Great doubt was thrown upon this statement by experts, but the fact came to be recognised after the publication of an important paper by Dr. Sumpner on this subject, which was read before the Physical Society in November 1892, wherein he treated the matter mathematically.

Ground lamps illuminate not from the filament itself, but from a screen of ground glass having a vastly larger surface than that of the filament, and consequently the intensity of the illumination at a given point of the screen will be less than that at any point of the filament. This ground-glass screen is the glass globe of the lamp. When obscured lamps are used, the result is that no surface of such intense illumination exists in the room: which produces, in the first place, a source of protection to the eye; in the second place, the surface of illumination being greater, intense shadows are avoided; and, thirdly, the ground surface being crystalline it breaks up the light, and the direct light is more equally diffused on the one hand, and a more equal reflection from the various surfaces of the room is produced on the other.

The writer has calculated that the area of ground surface in an 8 c.-p. lamp, with the normal conditions under which lamps are made, bears a relationship to the

filament of at least 1 to 150; *i.e.* the intensity of the light at a given point of the ground globe is at least 150 times less than that of the filament.

A further calculation was made, which under the circumstances can only be approximate, although the result is interesting. In the case of a gas flame produced by a good burner under normal conditions, half a square inch in surface gives the light of one candle, and two-thirds of a square inch of surface of an obscured glow-lamp also gives the light of one candle. The experiments and calculations made for obtaining the above-mentioned results were conducted with a view of examining the truth or falsehood of statements which were being made, to the effect that the electric light in houses injured the eyes. Even allowing for any small errors, which may have crept in in making these experiments, it is quite evident that the incandescent obscured lamp is decidedly more favourable for the eyes than is a gas flame. On the other hand, it is equally clear that an electric lamp with a transparent globe must be exceedingly injurious to the eyes. In many houses there can be little doubt that, even where the frosted lamps are used, the eyes may be injured on account of the excessive number employed; but, because some individuals commit this stupidity, that is scarcely a reason for condemning the whole system.

The following few remarks may be added in order that the reader may judge dispassionately as to whether the electric light is, or is not, injurious to the eyes. Both for the light and against it prejudices are very strong, and it is feared these arise from motives not altogether disinterested.

Everything that is seen is focussed by the lenses of

the eye upon the retina; and, as the sensitive back of the eye is very small and the angle of view considerable, obviously small objects looked at are, in the eye, reduced to microscopical proportions. Therefore, it follows that the images of the arc light and of the incandescent filament of the glow-lamp upon the retina are extremely small points of intense brilliancy. It is quite conceivable that such excitation of the retina may produce a kind of paralysis for the time being of those portions where this intense light falls, which loss of vitality may be temporary or may become permanent in a greater or less degree. That there is such a partial paralysis is evident from the fact that, when either of the lamps just mentioned is stared at from the usual distances where they are placed for use, the arc light or incandescent filament can still be seen, even after the eye turns away from the light to look at other objects. When these lights are protected by ground glass, the injury to the eye is no greater than that commonly caused by gas light (and the extent of which is now known by a long experience), since the images upon the retina occupy a larger area, and consequently the light at any point is of less intensity. The fair inference should be that the electric light is not hurtful in the case of arc lights when enclosed by opal or ground glass globes, and in the case of incandescent lamps when these are obscured. But it must be borne in mind that under no conditions is it desirable to stare at a light, be it even a candle; a simple experiment which may be tried by any one. Sensible people do not stare at the sun, although its light is welcomed by reflection from the objects in its rays.

There is a general impression that, whilst the work

that is being done should be illuminated, the eyes should be in shade. This, the author believes, is a great mistake, and tends to impair the sight in the long run (unless the light be much subdued, like that of a candle), far more than working with a light, diffused throughout the room, sufficient for the purposes required. With a shaded light, which screens the eyes, the source of illumination must be near the work, and the existence of the shade, which is generally white inside, increases the light in the direction in which it is used. The consequence is that the illumination is very intense. In order to prove the opinion just expressed, the author has made a series of experiments. He has observed the contractions of the iris in a mirror under various conditions, these comparisons being made with the contractions as they exist in the day, under conditions which most people would consider favourable for seeing comfortably. In the daytime, no one with healthy eyes would think of wearing shades.

In order to appreciate the advantages which arise from the use of currents of very high pressure, it will be desirable to refer to the result produced by a transformer when employed for lowering the pressure of the primary current for use on a secondary one.

Suppose the E.M.F. of the primary circuit is 2,400 volts (as upon the lines of the London Electric Light Supply Corporation), and a house has to be supplied with 60 amperes at 100 volts, *i.e.* a current for 200 8 candle-power lamps, then, when all these are in use, only 2·5 amperes of the primary current would be required to produce these 60 amperes in a secondary circuit.

A high-pressure direct current can also be transformed to a lower pressure by a special kind of motor, termed a

direct current transformer; but its use at the present time is very limited, on account of the difficulty of producing high-tension direct current machines. The Chelsea and Oxford Supply Companies employ this system.

This example brings to the mind very clearly why currents having high E.M.F. are employed for public supply, a very small conductor being able to carry an enormous amount of energy. Were it necessary to carry the low tension current from the works to the houses without great waste in the conductors, the latter would be of a size so enormous as to place universal electric lighting far beyond the bounds of possibility, unless the central station is close to where the energy is to be used. The waste in the leads is proportional to the square of the current. Therefore, if the current is doubled, the leads would have to be four times the section, in order that the waste might remain the same; three times the current nine times the section, and so on. To give a practical idea of the difference of waste, that is to say, fall of E.M.F. in a low-pressure and high-pressure system, the following figures may be considered.

Let two central installations each supply two thousand 8 candle-power lights, in the one case giving 100 volts, and in the other 1,000, which has to be reduced to 100 at the houses. Then if the resistance of the mains is 0·5 ohm, the fall of pressure in the 100-volt system would be 600 multiplied by 0·5 (since 600 amperes would be the current at 100 volts to supply 2,000 8 candle-power lamps), and this means a loss in the pressure of 300 volts. In other words, in order that the houses may obtain a current at 100 volts, the pressure at the central station must be 400 volts. The expense of

producing electric energy in this way would be prohibitory, and far larger mains would have to be employed—that is to say, a larger capital outlay at the start.

In the case of the 1,000-volt installation, only 60 amperes would be necessary to do the same work; consequently, if the same mains were used, the fall of E.M.F. between the works and the houses would be 60 multiplied by 0·5, or 30 volts. The pressure of the current at the station need o ly be 1,030 in this case; that is, 3 per cent. only would be the loss, instead of 75 per cent. as with the 100-volt system. This example shows the advantage of the high pressure very forcibly.

In the above examples the resistance of the houses has been neglected; but since this resistance is low, the results would not be bettered if the calculations had included this portion of the system. The present law permits a *total* variation of 8 per cent.

It must not be supposed that all the losses occur in the mains, although with the direct current most of the waste takes place in this direction. With the alternate system there is a considerable loss in the transformers themselves, which may be put at an average from 7 to 10 per cent. If these apparatus could always be worked with the most economical load, the loss would be very slight; but this naturally could not be done. Still, on balance there is much in favour of the alternate current system when the central station is far removed from the district it has to supply; and it must be borne in mind that, with the alternate current system, the heavier the load the more economical are the results, whereas with the direct system the reverse is the case.

All incandescent lamps, giving the same light, absorb practically the same power. For instance, a 100-volt 8

candle-power glow-lamp requires 0·3 ampere, or expressed in power by watts, $0·3 \times 100 = 30$ watts. If it is desired to find what current is required by a 50-volt 8 candle-power lamp, proceed thus: $\frac{30 \text{ (watts)}}{50 \text{ (volts)}} = 0·6$ ampere. To obtain 16 candle-power, 60 watts are necessary, and so on, the number of watts consumed in glow-lamps being nearly proportional to the light, as they are now made. Since 746 watts = 1 E.H.P. = 1 H.P. (= 33,000 minute foot pounds), and $746 \div 60 = 12·43$, it implies that theoretically 1 I.H.P. in the engine should light between twelve and thirteen 16 candle-power lamps, or twice this number of 8 candle-power lamps. Evidently this number cannot be obtained in practice, since there must be a considerable loss of energy in the production of the current. Under the best conditions, as many as ten 16 candle-power lamps can be lit for each I.H.P. of the engine, so that it may be roughly said that the commercial efficiency is about 82 per cent.

The efficiency of glow-lamps alters rapidly when the pressure of the current varies from the normal. Any variations in the pressure so low as 1 per cent. will show a marked difference in the light of an incandescent lamp, and, if such variation were spasmodic, the eyesight would soon become injured; hence the importance of a constant pressure.

A very small fall of E.M.F. below the normal (100 v.) makes a marked difference in a light. A rise or a fall of 1 volt above or below normal makes an increase, or a decrease, of about 2 candle-power only: after this, the differences are large. With a 10 per cent. fall a lamp will yield barely half the light it was intended to give,

although only one-tenth less current is passing. It is evident that, if the payment for current is to be fair, any company giving a pressure of 10 per cent. under that contracted for should receive a reduction of 50 per cent., and not of 10 per cent., in the payment, because the consumer does not care what energy he is taking; it is the light which he requires, and for which he is willing to pay. Since no company is likely to agree to such terms, it is of the highest importance that the public authority should protect the public against any variation of pressure in the mains from that stipulated for, in the same way as is at present done with gas companies. These remarks, when they appeared in a previous edition, were considered as very severe; but they have been fully justified by the action of the Board of Trade.

The above observations do not apply when the current is employed for cooking or heating purposes. To treat of lamps and their effect on the sight may appear a digression in a chapter on conductors, but it must be remembered that the whole principle upon which a house is wired is made subservient to the production of light in the most effective manner for doing a variety of work depending solely on the eyesight. It would, perhaps, in consequence, be the proper place to give a short table showing the heat produced by various sources of light. The table is a well known one, drawn up by the late Dr. Meymott Tidy.

By comparing the figures it will be noticed that the light given by wax candles is about the worst source of light when health is considered. The reason why half the population of the world has not been asphyxiated by their use is due to the fact that they are expensive, as well as being troublesome to fit in candle-

Light-producing material, equal to twelve standard candles	Cubic feet of oxygen consumed	Cubic feet of air consumed	Cubic feet of carbonic acid consumed	Cubic feet of air vitiated	Heat equal points of water raised to 10° Fahr.
Common gas . . .	5·45	17·25	3·21	348·25	278·6
Sperm oil	4·75	23·75	3·33	356·75	233·5
Paraffin	6·81	34·05	4·50	484·05	361·9
Sperm candles . .	7·57	37·85	5·77	614·85	351·7
Wax candles . . .	8·41	42·05	5·90	632·25	383·1
Electric light . . .	none	none	none	none	13·8

sticks; and, consequently, people have been content with a moderate amount of light from this source. There can be no doubt that the easier any illuminant is to manage, the greater is the amount of light people demand from it. When large quantities of light are easily available, the demand seems to be limited only by the expense. Assuming the truth of these conclusions, it might be predicted that, if the cost of the electric light could be reduced in any very great degree, future generations will light their rooms to an intensity necessitating people to wear blue spectacles. Even now, although in some drawing-rooms the lamps are shaded to a degree that a man would not be able to recognise his own son, in others there is a strong and an almost irresistible temptation to take up and open a parasol, if such a convenient shade were within reach. Notwithstanding all the advances which have been made in education, extremes of fashion prevail as absurd as were some of the customs of the middle ages.

It will be observed that, whatever be the amount of electric light in a room, the air is not vitiated, so that even a small bedroom is healthy, which could not be said of it were the ordinary illuminants used. Only let the electric light be made universal, and no more would

be heard of deaths from suffocation due to gas in small bath-rooms, or of persons poisoned by noxious fumes arising from gas leakage.

It is assumed that the incandescent lamp is used, which would invariably be the case in a house. It may be also remarked that the better to realise the differences in the heat given by electric glow-lamps and gas, it need only be mentioned that one 5-foot gas burner gives as much heat as 20 8 candle-power glow-lamps.

In connection with the electric light there have been numerous fires and other accidents ; but these, in every instance, may be traced to bad work or carelessness, so that users of electricity need have no fear, if only they employ competent people, and do not grudge money to secure the safety of life and property.

The following facts are given as affording a rough notion of the difference between gas and incandescent lamps in the lighting of a room. An ordinary sitting-room usually measures about fourteen by twenty feet, and twelve feet high. The cubical contents of such an apartment are 3,560 feet, and the amount of oxygen is approximately 710 cubic feet. If two ordinary No. 5 gas burners are used for illumination during a period of six hours (which is a fair allowance on a winter's evening), over sixty cubic feet of oxygen is converted into new chemical compounds unsuited for the support of life. Besides this, the gas, as generally supplied, is impure, which causes it to produce some of the most poisonous gases that are known. These disadvantages are completely absent with the incandescent light.

Almost all textile fabrics, leather, most metals, and a thousand other substances, are rotted or damaged by gas fumes. Hence the inadvisability of using this source of

illumination in libraries, picture galleries, and nearly all shops. One instance came to the author's knowledge not very long ago. A large linen-draper in the North of England wrote off every year, as a loss, a quantity of goods chiefly placed on top shelves and damaged by gas. As an experiment to prevent this loss, the electric light was resorted to, the installation costing about 2,000*l.* After two years' working, it was found unnecessary to make any allowance in the accounts for damaged goods, from which the loss had been 2,000*l.* a year (the exact cost of the installation); and the expenses of the lighting amounted to less than those of gas. There is no need of further comment on this point.

CHAPTER III.

TESTING.

WHEN the wiring of a house is completed, and even during its progress, the conductors have to be tested for insulation. Every fitting and every piece of apparatus intended to be used must also be tested. The accumulation of a great number of faults, apparently insignificant when taken by themselves, will show a large leakage on the system. Too much care, therefore, cannot be taken in avoiding the use of fittings which give the slightest indication of leakage between portions which will be of opposite polarity or to earth. As no substance is a perfect nonconductor, it becomes impossible to construct any fitting which shall have no leakage whatever. The presence of moisture in the air assists this result, especially as parts having opposite polarities are brought close together in many of the fittings. The consequence is that the more lamps there are in an installation, the greater will be the leakage indicated upon the system. Hence it is impossible to lay down that an installation shall have one standard of resistance and no other.

The greater the number of fittings in a house, the less will be the total resistance of the insulation. In the rules for the prevention of fire risks, issued by the Institution of Electrical Engineers, it is stated that the leak-

age should not exceed $\frac{1}{5000}$th part of the total current intended to be used in the installation when tested with a current having an E.M.F. equal to that intended for service on the system. However, if a better insulation can be obtained, it should be secured.

The writer was the first to suggest the idea of a leakage test for insulation, and it was adopted by the committee of the Institution of Electrical Engineers after a long debate. He urged that this method of testing was open to the most inexperienced, if provided with a suitable galvanometer ; and technically the test was as good as one taken with a bridge. It is satisfactory to find that the Board of Trade has adopted this method of measuring insulation resistance, so that it may now with the more confidence be recommended in general practice.

Since there is a tendency for the insulation to fall, the leakage to be permitted at the start should be from 10 to 100 times smaller than that mentioned above.

Frequently the opposite state of things arises, *i.e.* the insulation improves. This happens when the house has recently come out of the hands of builders and there is much damp about, so that sometimes it is exceedingly difficult to obtain anything like insulation without first thoroughly drying the house by means of fires. The proper method is to make the insulation tests by means of a Wheatstone bridge. But to use this properly requires a special knowledge, and the instrument is expensive.

It is not proposed to describe how to use a Wheatstone bridge, as a full explanation of the method may be found in many text-books. The most comprehensive book on matters concerning testing is that of Mr. Kempe.

A convenient form of portable bridge, illustrated in Fig. 9, is made by Messrs. Nalder.

When the galvanometer is separated from the bridge

Fig. 9.—Nalder Brothers' Portable Bridge.

there is probably none better for general work than the dead-beat one of the D'Arsonval Deprez type. This is shown in Fig. 10, with the cover off.

Two improved scales are shown for use with this or any

other reflecting galvanometer, and they are made by the same firm.

Fig. 11 is virtually a scale on the same principle as that in general use, only an electric lamp is employed for the light and the scale is transparent.

Fig. 12 is a form of scale with which the readings are taken by means of a telescope.

A simple way, which can be employed by most persons having an elementary knowledge of electricity, is to take

Fig. 10.—D'Arsonval Deprez Type Dead-Beat Galvanometer.

the measurement by the deflection method. The values of the deflections are ascertained by the makers of the instrument, which is a galvanometer, and are supplied with it to the purchaser.

One of the best and simplest forms of such apparatus consists of a high resistance galvanometer of the Post Office pattern, and a few portable Leclanché cells; the whole contained in a box which can easily be carried. The case has two terminals on its outside for attaching

the wires. The majority of these apparatus now in use have been made by the Indiarubber, Gutta Percha, and Telegraph Works Company of Silvertown.

Every piece of apparatus which has upon it metallic parts of opposite polarities, must be tested with this instrument, in order to ascertain whether any current traverses its insulating portion. If the galvanometer needle does not move, the fitting may be passed. The

Fig. 11.—Scale with Electric Light.

same process should be gone through with lamp pendants, brackets, and electroliers, to see whether any deflection takes place, on connecting each lead successively to the metallic parts of these fittings through the galvanometer, taking care that the contact is not made where lacquer exists. The two leads should be tested also, for insulation between themselves. Switch- and fuse-boards, switches, cut-outs, ceiling plates, connector

plugs, and all other apparatus should be tested in a similar manner, with a view to learn whether there is any leakage in those parts which ought to be non-conductors.

The wiring may have two kinds of leakage. One may take place between the two leads, and the other

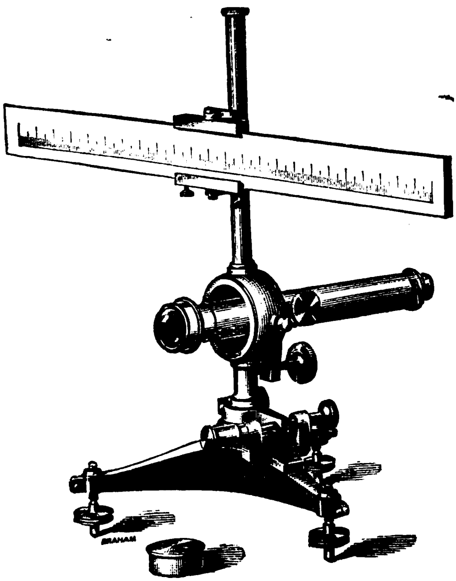


Fig. 12.—Scale and Telescope.

between one or both leads and earth. In order to test them for the first case, the wires from the testing instrument are attached one to each lead. If no deflection occurs, they are in good order in this respect. To test for earth, one wire from the galvanometer is connected to each lead successively, and the other wire is attached to a water- or a gas-pipe, preferably to the

former, by means of a solder, when again no deflection will take place if the insulation is good. If, when testing for earth, all the fittings and other apparatus being placed in the circuit (by switching all on), no deflection occurs, the insulation may be regarded as perfect. If deflection does occur, the number of degrees must be noted, and reference made to the maker's table, furnished with the instrument. It must be seen whether, from the number of lamps installed, the leakage is in excess of that which would be permissible; the margin allowed being greater as the number of lamps is larger. Should the insulation be below the mark, the faulty place or places must be sought for by disconnecting various portions of the system and testing them separately. When the system is tested for earth, the lamp switches should be turned on, and when tested for short circuit, the lamps must all be removed. Any apparatus usually placed between the leads must be put out of the circuit, by a switch or otherwise, during the test between lead and lead, but left in when making an earth test. To give an idea of the manner in which the deflections are made to indicate desired results, let it be supposed that when a test is taken over the whole installation, the result is, that the needle does not move, then everything is perfectly satisfactory; and, if twenty lamps are employed upon the circuit, a worse result must not be shown. For 100 lamps a deflection of 5 degrees might be permitted, and for 200 lamps perhaps 8; but the actual value of the readings will naturally depend on the sensibility of the galvanometer and the number of cells employed for the test. If a more sensitive instrument is required than the ordinary form supplied from the Silvertown works, it may be obtained by possessing

one of Messrs. Elliott's first-class Post Office pattern galvanometers.

It would be quite possible to employ the current off the Supply Company to make the test, were it not for two difficulties.

(1) When a house is newly wired, there is generally no means of obtaining this current, because the company has not yet made the connections.

(2) Leakage on the supply mains, and in other houses, would interfere with the test.

A very delicate apparatus has been devised by Major Holden in order that tests may be made off the supply mains, but it is more of a laboratory test than a practical instrument. Probably the best apparatus in the market at the present day for making insulation tests, and one that is extensively in use for this purpose, is that made by Messrs. Goolden (now Messrs. Easton, Anderson & Goolden).

It consists of two parts; one to produce a current, and the other upon which to read the insulation resistance (see Fig. 13). The current-producer is a portable magneto machine, which can give a current having an E.M.F. as high as 120 volts, without turning the handle at an excessive speed. The reading instrument has four terminals. Two of these are employed for the wires going to the generator, and the other two are for the lines to be tested, or line and earth. The scale is marked to read in megohms and thousands of ohms, so that the needle at once indicates the insulation resistance when a test is made. The indications being independent of E.M.F., the actual rate at which the generator handle is turned does not alter the result. There is a great advantage in testing with the same E.M.F. as is intended

to be employed in practice. Mr. Evershed has designed this instrument. The principle upon which it acts is the following.

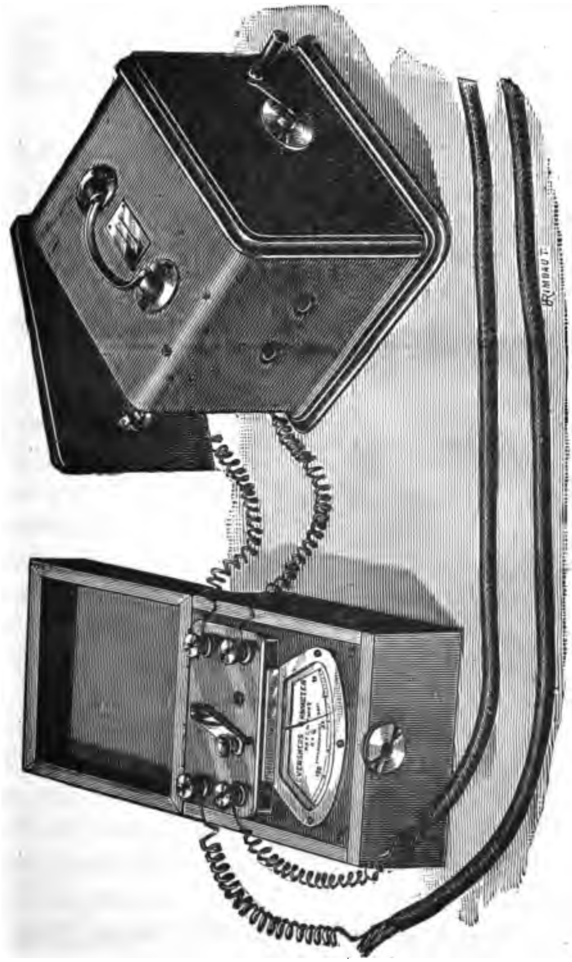


Fig. 13.—General View of Ohm Meter.

There are two coils at right angles to one another (see Fig. 14); one of high resistance (P) placed in shunt, and one of low resistance (C) connected in series with the leads (MM) to be tested. The coil (P) has a constant resistance coil (R) in connection with it. The current in these coils causes a magnetic needle (NS) to deflect, the needle being outside the coils and not within them.

The spindle of the needle carries a pointer, which indicates upon the scale. In the diagram, D shows the generator.

The instrument must be kept at a distance from magnets and iron during the tests, and a few feet should intervene between the generator and the indicator.

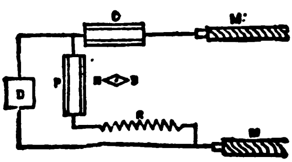


Fig. 14.—Diagram of Ohm Meter.

A very neat and useful testing galvanometer is shown in Fig. 15. It was designed by Mr. Raworth and manufactured by Messrs. Dorman & Smith, of Manchester. It consists of a good galvanometer, a resistance coil, and two cells; all contained in one case. The galvanometer can be slid out, without unfastening any wires. The cells also are removable. There are two terminals on each side of the case. In front of the dial there is a hinged mirror to enable readings to be taken in awkward situations. The plate shows the mirror hinged back. The cells and galvanometers are also shown removed from the case. When making ordinary tests with the cells, the terminals are so selected that the resistance coil is not in the circuit. When tests are made with current from an independent source, having high E.M.F., say, up to 100

or 110 volts, another pair of terminals is selected in such a way that the battery in the galvanometer case is out of

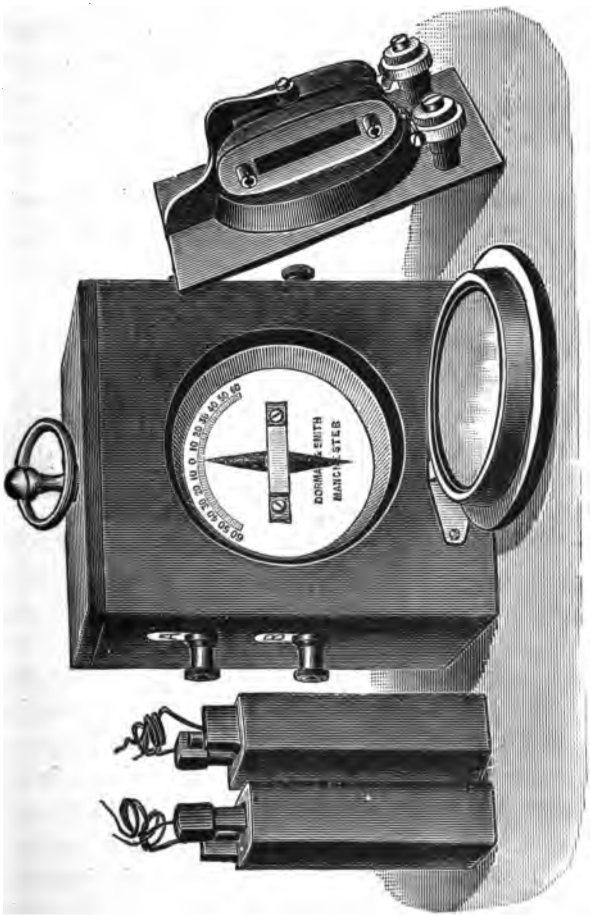


Fig. 15.—Raworth's Portable Galvanometer.

circuit and the resistance coil forms a portion of the galvanometer circuit.

As a simple test for earth, Woodhouse & Rawson's

pole-tester is sometimes fitted up as shown in Fig. 16. One tester terminal is connected with earth, and the leads are connected with the right and left of the contact-pieces of the switch. Consequently, one or the other lead can be placed to earth through the tester; and if any leakage exists, discoloration of one of the electrodes will result. When the tester is out of use, the switch-key is placed on a central false contact.

The author has brought out a simple little apparatus, similar in principle to this one. It is a high-resistance

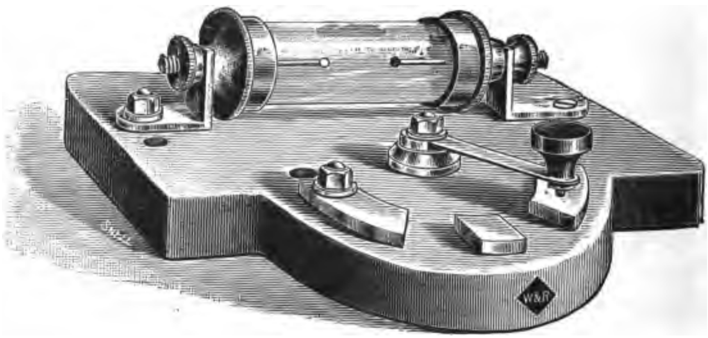


Fig. 16.—Woodhouse & Rawson's Leak Detector.

galvanometer, taking the place of the pole-tester, and a double spring key replacing the switch. This key is so arranged that no contact is made except when one end or the other of the lever is pressed. The lever is constructed in such a way that only one contact can be made at a time. The galvanometer itself is protected by a heavy iron case from outside electric influences. In the improved form there is an additional little switch which can assume two positions. Turned one way, the instrument is ready for testing; turned the other, it can be used as a voltmeter. The scale is graduated in

degrees, divisions of megohms, and volts. There is also an indicating needle which is set to the margin of safety and allowed in the house where the instrument is placed. It is only necessary for one of the servants every morning to press successively the buttons on the lever, and to note that the needle does not pass the fixed pointer on the dial. If this should happen, the fact will be reported to the head of house, and he will naturally call in some one competent to discover the fault. This indicator was the first of the kind which appeared.

When such an instrument is employed in a house, it is generally desirable to have an independent battery of dry cells and to place them in circuit after cutting the D.P. main switch, to make sure that any leakage indicated is that existing in the house and not due to any faults outside it. The manufacturers, Messrs. Elliott, will always mark the dial to indicate the limit of deflection permissible in any given installation, by making a red line against which is placed 'Danger.' This would render the house safe.

It should be mentioned that dry cells rapidly deteriorate unless in constant use. Hence a small magneto-machine might be employed with advantage in place of a battery, and the type of galvanometer chosen to suit the current in use.

The tests may be made with the lamps alight, and always when the current is on the lines. The addition of such an apparatus would not cost more than £3, and would tend to give confidence to the inmates of the house.

It must be pointed out that the main on being placed to earth, which shows the leakage, is not the one upon which the fault exists. This might have a fault, and it

will be discovered on placing the opposite one to earth. Many people have a difficulty in realising this. The following example will make it clear. Supposing the positive main has an injured place upon it and that the wire touches a gas-pipe, in which event there will be a large earth upon it, then no current will leave the system to earth, unless a leakage exists on the negative main. Now, if the negative is connected with earth purposely through an indicating instrument, it is quite clear that a current will flow between the mains through the earth. Again, if instead of putting the negative main to earth, the positive one were connected to earth through the indicating instrument, since the fault and the instrument earthed are both upon the same piece of wire, no flow of current would result. But it must be pointed out further that, if the fault on this positive main were at a very great distance from the point connected to earth through the testing apparatus, there might be a small leakage due to the difference of potential between the two points on that main. This case would probably never arise in connection with electric light systems in houses. But, in any event, were a leakage to be detected in this manner the deflection of the galvanometer would always be less than when the test is made with the opposite main. The same method of making a test can be employed to ascertain whether the primary and secondary systems of transformers are short-circuited. When testing, the supply mains should be disconnected or cut with a D.P. switch. The use of the Cardew safety device in the house, and the earthing of the framework of the transformer, will, to a great extent, remove the possibility of high potential entering the house.

When the house is supplied by a public company, it

is well to ascertain the insulation tests they may require, and note the corresponding deflections on the galvanometer with which the tests are to be made.

It is frequently necessary to test an installation by observing the behaviour of the machinery and apparatus, when the number of lamps in use is varied. It is evident that varying the number of lamps is equivalent to varying the resistance of the dynamo outside circuit. The more lamps lighted, the lower this resistance. Consequently, if the house mains are connected to a variable resistance, suitably divided, all the effects, which would be produced upon the machinery by giving current to one or more lamps up to the maximum number, may be obtained. When a resistance is employed to produce equivalent effects, it is termed an artificial resistance; and, if such an apparatus is placed in the dynamo-room, the behaviour of the installation may be tested and examined at any time without the necessity of turning on and off the lamps, motors, and so forth, in the house. Artificial resistances consist of ordinary resistance frames suitably divided to obtain the steps required, and the section of the wire is so chosen as to carry the current without overheating. Wire of a very small section may be employed, if the frame be placed in a water tank; and one convenient form of making an artificial resistance is to attach the mains to two plates of metal which are put in a vessel containing water, the latter acting as the resistance, the variations in resistance being made by moving one of the plates nearer or further from the other. When the liquid resistance is required to be low, a dilute solution of one part sulphuric acid to nine or more parts water may be employed in the place of water.

Professor Fleming has devised and patented an excellent form of resistance, which will no doubt be largely used. It resembles the old-fashioned toy of the "bees" sliding on threads, but with the "bees" absent, and he calls each apparatus a cage.

Those which the Professor was kind enough to construct for the author have each a resistance of 100 ohms. Consequently, on a 100-volt circuit 1 ampere will flow through the resistance, which may be left on continuously. It follows, therefore, that each cage can dissipate 100 watts. If two such resistances are placed in parallel, 2 amperes will flow from the mains; if three, 3 amperes; and so on. Therefore, if a battery of such cages be set in a frame, it is only necessary to place a lamp switch for each cage on the frame, or in any other convenient position, and to turn on one, two, three or more lamp switches in succession, to obtain a current of 1, 2, 3 or more amperes, as may be required. With higher voltages many cages are placed in series. The writer ventures to predict that this way of using resistances, which would not have been suitable with the older forms of resistance frames, is likely to supersede present methods on account of its simplicity and convenience.

It is often necessary to ascertain the candle-power of lamps. Although the 8, 12, 16, 25 and 32 c.-p. lamps give different amounts of light, yet their respective brilliancy is not very easy to distinguish with the eye, when any two are tried in their successive order of lighting power unless placed side by side. The lamps have marked upon them the manufacturers' letter, for reference to their books, the E.M.F. at which they should be worked, and the candle-power; but, when the lamps are obscured, these marks frequently become obliterated, and since

the globes are very similar for all the lamps mentioned, the eye, in the absence of testing instruments, is the sole means of ascertaining the comparative power. These observations may be considered as partaking of the nature of splitting hairs, but the author was recently appealed to as to how it was possible to distinguish between these lamps, which the committee of an institution was unable to do. Payment was being made per lamp according to its power; and the lamps, being observed in their respective positions throughout the building, it was practically impossible to settle the classes as no marks were visible upon them. The following recommendation was therefore made: on a piece of wood are to be attached two lamp-holders, a few inches apart, connected to the mains by means of a flexible cord with a connector. In one is placed a lamp of known candle-power, and in the other the lamp to be tested. In this way every lamp may be assigned to its proper class, and when it is obscured, the candle-power may be written with pencil on the globe. Old lamps must be compared with old lamps kept for comparison standards. Such a test is also useful for observing the condition of lamps on their arrival from the company supplying them.

The author suggested staining the plaster of Paris with various colours when mounted with this material, as in the case with socket lamps; and thus distinctions could easily be made. It was proposed to consider the earlier letters of the alphabet as representing the lower candle-power: for instance, 8 c.-p., green; 16 c.-p., red; 32 c.-p., white.

Lord Kelvin's standard instruments are now so largely employed, that it appears desirable to give the instruc-

tions which are sent out with those mostly in use. The author has made every endeavour not to appropriate the work of others and thus mislead his readers into the idea that it is his own, and finding it very difficult to give the instructions required for the Kelvin instruments without borrowing largely from the wording of the instructions sent out with them, he obtained permission to give these instructions word for word as they appear in the pamphlet issued by Lord Kelvin.

INSTRUCTIONS FOR USE OF THE MAGNETO-STATIC CURRENT METERS.

(N.B.—See Vol. II. for the descriptions and figures.)

The instrument should be levelled in accordance with the attached spirit level, by means of the levelling screws.

To adjust the pointer to zero.—(a) Loosen the two milled headed screws clamping the magnet frame and turn the frame round till the pointer stands at zero. (b) Re-clamp the frame by tightening the two screws.

Adjustment of the scale.—The scale is firmly clamped in its place before sending the instrument out, and this position is marked by two lines on the outside of the case, one horizontal and the other vertical, just below the 0 of the scale. The horizontal line is engraved below the movable top of the instrument, and the vertical one on the side of the case. Should the top of the instrument have been inadvertently moved, and the scale thus put out of adjustment, it may be set right by slightly loosening the two slotted screws and turning the top round till the extremities of the two lines coincide.

If the needle should by accident be slightly bent (if it is bent so largely as to be perceptible to the eye, it ought to be straightened by hand as nearly as may be), and so render a new adjustment of the scale necessary, this may readily be made in the following manner:—Set the zero, by the field magnets, to the division 50 at the middle of the scale, then join the instrument in series with another current instrument of convenient form, and pass a current through both sufficient to give a deflection of about 40 divisions on the magneto-static instrument; reverse the current on the magneto-static instrument only, and set the scale so that equal deflections, read in divisions, are given on each side of the zero for equal currents, as indicated on the auxiliary instrument. The zero must, of course, be reset by the magnets every time the scale is moved. When the scale has been adjusted to this position, firmly clamp the top of the instrument by the two slotted screws, and again mark the position of the horizontal line on the outside of the case.

Adjustment of constant.—The constant may be quickly varied as follows:—Join the instrument in series with any reliable current instrument of known accuracy, such as the deci-ampere balance, and pass a convenient current through both instruments, observing the readings. Break the current, loosen the two upper pair of slot-headed screws, and turn the top system of magnets relatively to the lower, so that the similar poles of the two systems are brought closer together or moved urther apart, according as it is desired to make the instrument respectively less or more sensitive. Re-clamp the screws and adjust the zero as described. Again, make the current and note the reading on the two instruments. The desired reading on the magneto-

static may be obtained quickly after one or two approximations, care being always taken to readjust the zero after each movement of the top magnets.

When convenient, it is always best to standardise the instrument in the place where it is to be used ; but when it is intended to move it from place to place, it should be standardised in such a position that when the needle is pointing to zero, it is in a direction approximately east and west.

Instructions for the Use of the Portable or Marine Voltmeters and Amperemeters.

To set up the instrument.—When in use, the instrument should be supported with its scale approximately horizontal.

Adjustment of the zero.—This adjustment is made by the maker, and it will rarely, if ever, require revision. Should such be found necessary at any time, it may be very easily effected as follows :—

(a) Unscrew the movable cap of the top resistance coil.

(b) Turn the torsion head until the needle points to zero.

(c) Replace the cap, screwing it down firmly.

Instructions for the Adjustment of the Standard Balances.

The instrument should be levelled in accordance with the indications of the attached spirit level, by means of the levelling screws, on which the sole-plate of the instrument stands.

In the centi- and deci-ampere balances, the beam

can be lifted off its supporting ligaments by turning a handle attached to a shaft passing under the sole-plate of the instrument. This shaft carries an eccentric, on the edge of which rests the lower end of a vertical rod fixed at its upper end to a tripod lifter. When the instrument is to be packed for carriage, or when it is to be removed by hand from place to place, the lifter should be raised ; but when it is fixed up for regular use, it is advisable to keep the beam always hanging on the ligaments. In the deka-, hekto-, and kilo-ampere balances there is no lifter, but the beam is packed by placing distance pieces between the two halves of the suspension trunnions and screwing them together by means of milled headed screws provided for the purpose. When the instrument is unpacked and prepared for use, these distance pieces must be taken out and placed in receptacles provided for them in the weight box.

A set of four sliding weights, of which the carriage constitutes one, is supplied with each instrument. The carriage is fitted with an index to point to the movable scale, and is intended to remain always on the rail. One or other of the weights is to be placed on the carriage in such a way that the small hole and slot in the weight pass over the conical pins. The weights are moved by means of a slider, which slides on a rail fixed to the sole-plate of the instrument, and carries a pendant with a vertical arm intended to pass up through the rectangular recess in the front of the weight and carriage. The slider and weight are shown in position in the figures. (See Vol. II.) The slider is moved by silk cords, which pass out at the ends of the glass case. When the cords are not being pulled for shifting the weight, their ends should be left free so that the pendant may hang clear of the weight.

When a weight is to be placed on, or removed from, the carriage, the slider should be drawn forward at the top until it is clear of the weight, and then pushed to one side until the weight is adjusted, when it may be replaced in position in a similar manner.

Cylindrical counterpoise weights, with a cross-ba passed through them, are supplied for the purpose of balancing the sliding weights when they are placed at the zero of the scale. The sliding weight should be placed so that the index of the carriage points to the zero of the scale, and the proper counterpoise weight should be placed in the trough, fixed to the right-hand end of the beam, with its cross-bar passing through the hole in the bottom of the trough. The flag, which is attached to the cross trunnion of the beam, should then be turned, by means of the handle projecting from under the sole-plate, until the index on the end of the movable scale points to the middle one of the five black lines on the fixed scale opposite to it. Care must be taken, when making this adjustment, that the fork which moves the flag is not left in contact with it, as this would impede the free swing of the beam. The fork should be turned back a little after each adjustment of the flag, and, when the flag is being adjusted, it is better to watch the flag itself and make successive small adjustments until the beam stands at zero than to make successive trials by pushing round the handle while watching the position of the index.

If the ligament has stretched since the instrument was standardised, the index at one end of the movable scale will be found to be below the middle line on its vertical scale when the index at the other end is correctly pointing to the zero position. The error so introduced would be

a small one, but it may be easily put right by slightly loosening the screws fixing the pillared frame, which supports the movable beam, to the base-plate, and raising it by slipping one or two thicknesses of paper below it until the indices simultaneously point to their zero position.

A lens is supplied with each instrument for facilitating accurate observation, either when reading the position of the weight or when adjusting the zero.

The vibrations of the beam may be checked so as to facilitate reading by bringing the pendant, which moves the weight, lightly into contact with it, in such a way as to give a little friction without moving the weights.

In using the centi-ampere balance as a voltmeter, when great accuracy is required, care must be taken that the effect of change of temperature, in changing the resistance of the coils of the instrument and of the external resistance coils, is allowed for; and in this use of the instrument it is advisable to employ currents such as can be measured by the lightest weight on the beam. When the instrument is to be used as a voltmeter, four resistances are provided, three of which are each 400 ohms and the fourth is less than 400 ohms by the resistance of the coils of the instrument at a certain specified temperature. The smallest resistance is intended to be included by itself in the circuit when the lowest potentials are being measured, and in series with one or more of the others when the potential is so high as to give a stronger current than can be measured with the lightest weight on the beam. The correction for temperature is, for the copper coils of the balance, about 0·38 per cent. per degree Centigrade, and for the platinoid resistances about 0·24 per cent. per degree Centigrade.

Instructions for the Use of the Multicellular Electrostatic Voltmeter.

When received from the maker, the indicator needle with attached vanes will be found supported by means of the thumbscrew below the instrument, and also by the circular lifter, or checker, turned up so that the weight of the needle and vanes is taken off the suspending wire.

The scale is graduated to read directly in volts.

To set the instrument up for use.—(a) Unscrew the thumbscrew, and turn down the checker, so that the needle swings clear; (b) Level the instrument so that the spindle of the vanes passes down centrally through the intersection of the two black cross-lines on the sole-plate.

To adjust the zero, if necessary.—Unscrew the cap on the top of the tube, remove the washer, turn the torsion head by means of the forked key until the pointer stands at 0 on the scale. Replace the washer and screw on the cap again. Before adjusting the zero, turn the switch so that the insulated cells are in metallic connection with the case. (A wormwheel device is now employed for adjusting the zero.)

Arrangement for portability.—When the instrument is to be removed from place to place, see that the needle is lifted by turning up the checker, and when it is packed for use as a portable instrument, always screw up the thumbscrew as mentioned above.

Vertical Electrostatic Voltmeter.

To set up the electrostatic voltmeter in working order :—

a. When received from the maker, the vane will be

found raised from its bearings, with its knife edges held in two slots cut for that purpose in the guard rings, and securely fixed in this position by the screwed stop-pin passing through its upper end.

b. Having removed the glass door of the case, place the movable plate or vane on its knife-edge support, handling it very carefully lest it be bent or twisted in the operation. A line, drawn lengthwise on the surface of the movable plate, and passing through its intersection with the knife edge, divides the portions above and below the knife edge into unequal parts. When the movable plate is properly placed, this line is just seen behind the vertical edge of the fixed plate when the pointer indicates zero ; and the smaller segments of the movable plate are then hidden from a front view by being between the fixed plates.

c. To detect, and if necessary correct, any accidental bending of the pointer, with reference to the attracted portion of the movable plate, hang one of the weights on the lower knife edge ; take the round pin sent inside the case, and with it press the movable plate in between the fixed plates, until it rests in the two V-notches near the upper end of the vertical edges of the fixed plates ; holding the pin so, rotate it about its axis, and observe that the pointer indicates a small red line seen on the scale in the neighbourhood of division-number 35.

d. Remove the weight, and see whether the movable plate is in neutral equilibrium.

If it is so, the index will move very slowly along the scale, and will come to rest somewhere within its range. If the index rest against *one* of the stop-pins, screw out, or in, the nut on the horizontal screw attached to the lower end of the vane until the pointer comes to rest on

the scale. If the index rests very definitely at one point of the scale and vibrates about it, the movable plate has too much stability; if it is found that the index will rest against both of the stop-pins, but will not rest at any other point on the scale, the movable plate has too little stability.

The stability can be adjusted by screwing up or down the nut on the vertical screw attached to the lower end of the vane. These adjustments are provided by the maker, and will generally be found to be nearly enough correct.

e. After hanging on the weights, adjust the pointer to zero by means of the screw levelling feet on the case of the instrument.

It is often necessary to make the current, passing through an ammeter, some known value. This is effected by placing in the circuit a variable resistance, which is adjusted until the instrument indicates the desired current. For example, supposing it is required to standardise some ordinary form of ammeter, this instrument is placed in series with a Kelvin standard balance and a variable resistance. Then the latter may be adjusted until the balance indicates, say five amperes; the reading of the instrument under observation must be noted, and if it does not agree with the standard, then the adjustments must be altered to make it do so. If these adjustments do not exist, then the instrument has some constant which can be easily calculated. A few observations are next taken with different currents, and in this manner. The ammeter under test can be either adjusted to read correctly or else the constant can be

found; and, if neither of these is possible, the apparatus may be rejected as worthless.

Most forms of artificial resistances are not available for such observations, since every intermediate resistance cannot be obtained.

Wheatstone's rheostat is a resistance which may be continually varied without any step. It consists of two drums, one made of a non-conducting material, and the other of metal, and a long wire wound on the cylinder in such a way that in one extreme position the whole of

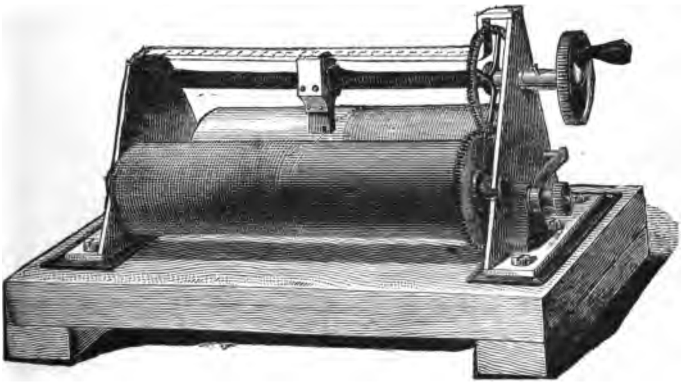


Fig. 17.—Rheostat.

the wire is on one cylinder, and in the other extreme position the whole of the wire is on the second cylinder. It will therefore be clear that, by winding the wire from one cylinder on to the other, every intermediate resistance can be made between maximum and minimum. The wire upon the metal cylinder does not count, for the current traverses the cylinder and not the wire; in fact, only the resistance of the wire upon the non-conducting cylinder is that which is measured. Lord Kelvin has improved this rheostat in such a way that the dis-

advantages which originally existed are removed. These disadvantages were that the wire and metal cylinder tarnished, so that the electrical continuity was impaired. The instrument is shown in Fig. 17.

The Wirt rheostat, spoken of in the preceding volume, is also a useful instrument for standardising, as well as for other purposes, and can often be employed in conjunction with the Kelvin rheostat.

Voltmeters, which contain coils, may be adjusted by standard instruments in the same way as ammeters as just mentioned. But the electrostatic instruments are best

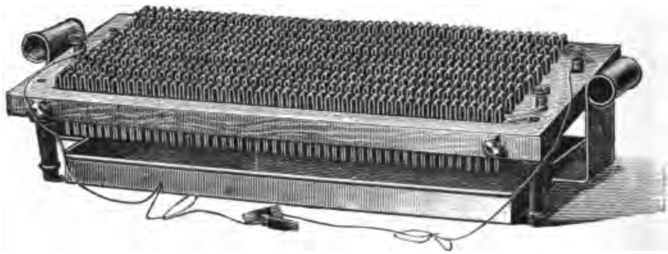


Fig. 18.—Voltapile.

standardised in another way. The apparatus for carrying this out is illustrated in Fig. 18. It also is one of Lord Kelvin's devices. The apparatus consists of a large number of couples of zinc and copper, mounted in a frame. Usually there are 500 such couples. The total pressure which this battery is capable of giving is not far short of 500 volts. There are little metal pegs which can be pushed in between the couples in such a manner as to obtain any voltage desired up to the maximum. The frame is mounted on short legs, and below the apparatus will be noticed a tray with a handle at each end. This tray is filled with water, and when lifted, the ends of the

couples dip into the water, which remains, by capillary attraction, between them after the tray is rested on the table again. A standard instrument is now connected with the battery, and one of the pegs is shifted between the couples until the required reading is obtained, say for instance, 100 volts. The voltapile now being arranged to give a pressure of 100, the other instruments which require to be adjusted are connected with this battery, and the pointer must be made to read 100 volts. Then the process is gone through again for a few other voltages, in order to observe whether the readings are correct throughout the scale. It must be remembered that this little battery, or voltapile as it is termed, gives practically no current, and therefore it is only serviceable for standardising electrostatic instruments.

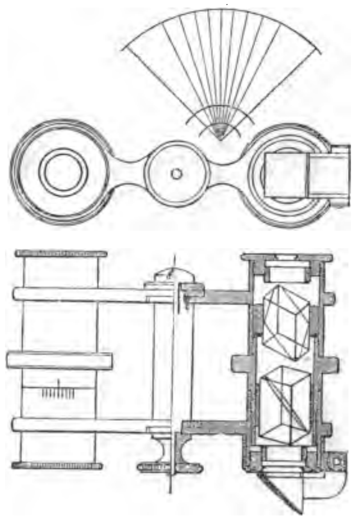


Fig. 19.—Diagram of Photometer.

Although the definitions of ampere, volt, &c., as adopted by the Board of Trade, do not enter into practical work, it may prove of some interest to know what they are.

The standard legal ohm is defined as the resistance of a column of mercury, one square millimetre in section and 106·3 centimetres long; the temperature of the mercury being that of melting ice.

The standard legal ampere is an unvarying current

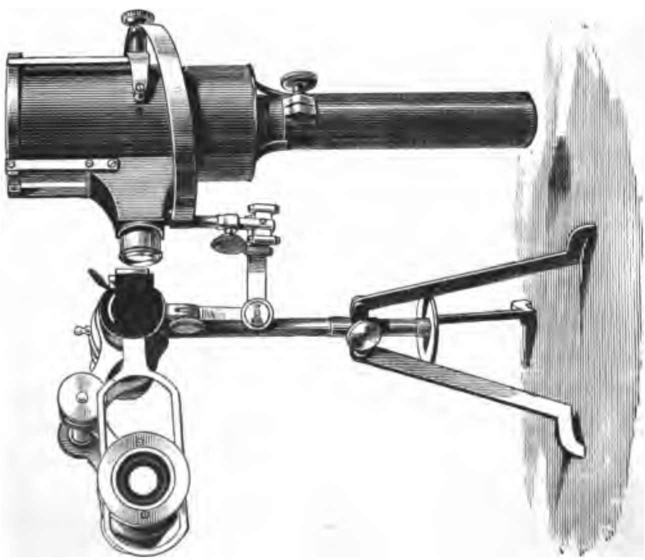


Fig. 20.—Photometer. Front View.

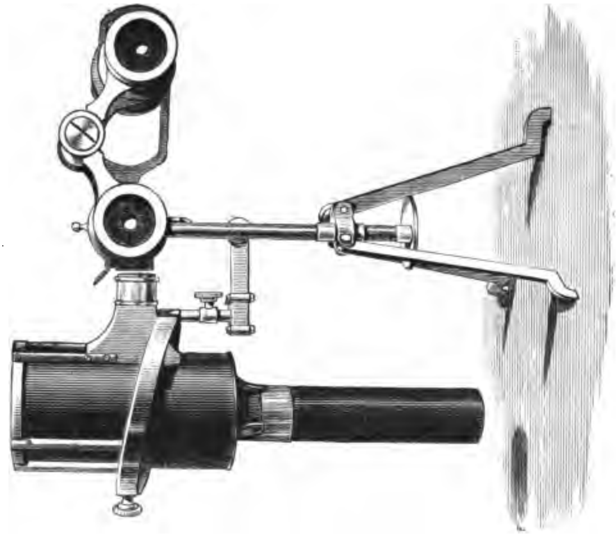


Fig. 21.—Photometer. Back View.

passed through a solution of nitrate of silver in water, which will deposit silver at the rate of 0·001118 gramme per second. The apparatus for conducting this experiment is defined by the Board of Trade.

The standard legal volt is a pressure which, if steadily applied to a conductor whose resistance is 1 ohm, will produce a current of 1 ampere.

A standard legal alternating pressure of 1 volt means a pressure such as that the square root of the time average of the square of its value at each instant in volts equals unity.

A standard legal alternating ampere is a current such as that the square root of the time average of the square of its strength at each instant in amperes is unity.

Many types of photometers exist for measuring the unknown value of a source of light with one of a known value. It is not proposed to give a description of the large variety of instruments which are made for this purpose. The common form of Bunsen photometer is so well known, and on the whole so convenient, that for all ordinary

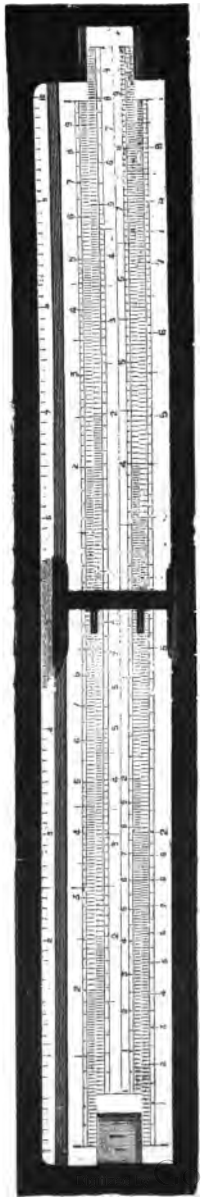


Fig. 22.—Slide Rule.

purposes it may be employed. The chief difficulty to be encountered with all photometers is to obtain a perfect standard source of light, and up to the present day there is not one, though many exist quite good enough for all practical requirements. The author brought out a small instrument, which, perhaps, has not the accuracy of some of the larger ones, but readings may be obtained with very close approximation to the truth. Its main advantage is that it can be carried in the pocket with ease. The principle depends on the cutting off of light by means of two nicol prisms, as used in the polariscope. To all appearance it is an ordinary binocular. A paper on the subject was read before the Institution of Electrical Engineers, which may be found in the Proceedings, part 105, vol. xxii. Fig. 19 represents the instrument diagrammatically, one tube being in section.

The lower drawing is a horizontal appearance; the middle one is the end view with the prism over the end of one tube, which reflects the light from the standard from other comparative sources of illumination. The upper divided arc gives an idea of the angle through which one of the nicols is turned to diminish the light from unity to zero by tenths.

Figs. 20 and 21 show the general appearance of the instrument, on its tripod, as seen back and front. The portion hanging in gymbals at the side contains a standard candle or any other standard source of light, a variety of details being carried out in respect of the candle for securing the same illumination under all conditions, including, amongst others, a little screen, so as only to use a small portion of the candle flame. This apparatus is very useful for comparing the light in a room with that out of doors

(no comparison radiant is then used) for photographic purposes.

An instrument has just appeared which supplies a long felt want. The apparatus gives the means of plotting the E.M.F. curve of an alternate current; it also serves as a means to discover the "lag" of E.M.F. in a circuit. The efficiency of a system depends so greatly upon the E.M.F. curve, that a small apparatus for this purpose is invaluable. The instrument consists of a simple synchronous alternate current motor, with a means of measuring the E.M.F. at all points of the circle upon a voltmeter. It is evident that, since one revolution of the moving part of the motor corresponds to a complete period, the E.M.F. measured at various points around the circle will give the E.M.F. curve, if plotted on paper. This is but a brief description of the arrangement. Messrs. Nalder are the makers of this curve-plotter and instructions accompany the instrument.

The slide rule is a valuable adjunct to the engineer. The one now almost universally in use is known by the name of the maker—the Gravet slide-rule. This is shown in Fig. 22.

CHAPTER IV.

METHODS OF WORKING.

As explained in Vol. I., when a dynamo is charging the cells, the E.M.F. on the lines is raised at least 10 per cent.; which may cause injury to, or may break, the lamps. Such a rise of pressure is of no consequence when charging ceases before lighting hours; but in general there is no certainty of this being done. Therefore, measures have to be taken to keep at all times the E.M.F. within the proper limits on the house mains. The methods for doing this will be described a little further on, but the circumstance must be here pointed out.

Dynamos, excepting those compound wound, give different E.M.F.s for different currents taken from them when running at one speed. These variations may be drawn diagrammatically, represented by curves called "Characteristics;" and every dynamo has its own peculiar curve. A perfect machine would give the same E.M.F. for all currents, when running at one speed; and the curve would become a straight line. Good dynamos have curves approaching this form for all currents within their capacity.

The shunt-wound dynamo is best suited for charging an accumulator. The series- and compound-wound dynamos are liable to have the polarities of their field magnets reversed, should the E.M.F. at the terminals

approach very near to, or fall below, that of the cells, when great damage may be caused before the cut-outs have had time to act. Some makers manufacture a "special compound-wound" dynamo for use with cells; but it is best to have the right thing at once, instead of resorting to makeshifts.

In a series-wound machine, the E.M.F. rises with an increased current; in a shunt-wound dynamo, the reverse takes place, and the compound machine is wound partly series, partly shunt, so that the E.M.F. is practically constant at a particular speed for all currents. Only the shunt dynamo claims special attention here. This dynamo has a falling curve (*i.e.* the E.M.F. falls as the current in the outside circuit is increased), due to three reasons. First, the armature absorbs more E.M.F. as the current is increased; second, as the outside resistance is lowered, the shunt current becomes less, and the field weakens; third, the current in the armature reacts upon the field. As the outside resistance is increased, the E.M.F. rises to the work. Many have supposed that a shunt machine will always respond to the work in a definite and suitable manner. This is not the case in good dynamos, because, by reason of their construction (consult Professor Sylvanus Thompson's book on the subject), the curve is nearly straight for all currents within their capacity; and such modern dynamos are in general use, although those with falling curves have certain advantages in small installations, where waste is not of great consequence. If the terminals of a shunt dynamo are short circuited, no current flows, because no current traverses the shunt circuit to create a field.

Dynamos give a different E.M.F. in proportion to the speed, but if a much higher E.M.F. be required than

was originally intended, then two things must be considered. The first is to ascertain whether the armature is strong enough to withstand the increased speed; and secondly, whether it will not become necessary that the shunt resistance should be increased by inserting an outside resistance, to prevent too much current passing, which would overheat the wire. In dynamos intended to run at two speeds, it is usual to place the shunts parallel for slow rates, and series for fast; in this way the use of an outside resistance is avoided. The E.M.F. and speed are not exactly proportional, for, as the E.M.F. rises, more current is sent round the field magnets; and the field becoming stronger, the E.M.F. has an increase due to this cause also, inasmuch as the iron of the magnets is not near saturation point in modern dynamos, except where they have been made for some special purpose. Yet, within small limits, the speed and E.M.F. may be taken as varying together directly, after the speed for which the machine was intended to run has been reached. The relations between the speed (limited by the strength of the armature), field, and resistance of the armature (*i.e.* number of turns and size of the wire) are the data which determine the E.M.F. and current curve; and the diameter of the armature wire limits the current, which can be produced without injury to the machine. The general behaviour and qualities of the dynamo have now been considered.

As to the cells, it has been shown in Vol. I. that their E.M.F. is practically constant, but rises somewhat as the charging proceeds, and mostly at the end of the charge.

Three things may occur when the dynamo and cells are combined.

1. The dynamo may have an E.M.F. higher than that of the cells. In this event, they will charge.

2. The E.M.F. of the two may be equal, consequently no current passes.

3. The E.M.F. of the dynamo may be less than that of the accumulator. In this case the cells will discharge into the machine, and run it as a motor. Appliances should be placed in the installation to prevent this.

Since the lamp mains are branched from the ends of the accumulator—or, in other words, it would be more correct to say that the house and dynamo leads are one and the same, with the accumulator placed between them in the same way as a lamp—it is necessary to examine what occurs when a current is flowing in these mains. Case 3 may be passed over, because should it occur, it must be regarded as due to neglect or accident.

In case 1, it is evident that, so long as the E.M.F. is higher than that of the cells, all current going to house mains must come from the dynamo; this, in fact, supplies the light and charges at the same time.

In case 2, half the current is supplied from the cells and half from the dynamo. But it does not in practice necessarily follow in this proportion, unless the resistance of the dynamo leads be extremely small and the internal resistance of the battery very low.

There is, however, one more case in considering the house leads. It is possible to raise the E.M.F. of the dynamo slightly above that of the cells, so as not appreciably to charge them, and yet supply the current to the house. This the author terms "balancing point," and then is gained the greatest advantage possible in steadying the light by the use of an accumulator.

On more current being taken to the lines after the balancing point is reached, the dynamo and cells begin to supply equal quantities, since the E.M.F. of the dynamo falls slightly for the increased current, and the E.M.F. does not recover itself for this diminished current, because the strength of the field has been altered.

The charging current must not be switched on until the E.M.F. of the dynamo is higher than that of the cells, say from 5 to 10 per cent.; and the proper moment to switch on may be ascertained by observing a voltmeter. For the voltmeter may be substituted two lamps, similar to each other, placed side by side, one lit from the dynamo and one from the cells, as proposed by Mr. Melhuish. The current is switched on, when the lamp lit from the dynamo is observed to be the brighter one. But the best way is to have an automatic switch, putting on the current when the correct E.M.F. is reached. The apparatus for this purpose was described in Vol. II.

As the E.M.F. of the cells rises and opposes the charging current, tending to lessen it, so also does the E.M.F. of the dynamo in a machine with falling curve; but in the best machines this rise is inappreciable. Therefore, if the current is to remain constant, certain devices in the form of governors must be introduced. A method of altering the E.M.F. of the dynamo is to place resistance, in and out of the shunt circuit, by hand. In this way a fairly constant current can be obtained.

It might be supposed that a constant current dynamo would be the right thing for keeping the charging current constant. This is true, if charging is not done during lighting hours; but when this is not the case, such a

dynamo is unsuitable. It is also less efficient than are the usual forms.

The automatic means of keeping the current constant will be presently explained.

The resistances required to be inserted for this purpose are small compared with that of the shunt. Consequently, the characteristic of the machine remains unaltered, and sparking is not produced at the commutator if the brushes have been set for the load.

The cells tend to steady the light when the prime motor is slightly irregular in speed, at such times when no current is flowing through them; also, when they, as well as the dynamo, are delivering a current to the lines. It is then that the field for the armature to turn in is kept constant; and the variations of E.M.F. only will alter for any irregularity of speed, instead of variations for speed and field combined. At other times, also, the cells steady the light, but not to the same extent. Their action in all cases depends on the relation between the resistance of the cells to that of the lines, so that any increase in current, due to a rise of E.M.F., is divided between the cells and the lines in that proportion; and since the resistance of the cells is low, compared with that of the lines, the bulk of the increased current passes that way. Thus the current to the lines is kept nearly constant. It is therefore desirable to make the resistance of the cells as small as possible, apart from the other reasons already given.

"Potential" is often understood as implying difference of potential, which is equivalent to difference of pressure, commonly spoken of (although not necessarily the same thing) as the E.M.F. between any two points, and is measured in volts.

The pressure of a direct current falls in direct proportion to the resistance that is traversed, compared with the whole resistance of the circuit. For instance, if a wire, having a uniform section, and 100 feet in length, has a current flowing through it, the difference of potential between its ends being 100 volts, then the difference of potential, between a point upon the wire 25 feet from one end, will be 25 volts betwixt these places; if taken at a point 50 feet from the end, 50 volts, and so on; *i.e.* the fall in the potential between one end of the wire and any point upon it will be proportional to the *distance* the current has travelled along this wire. But if the wire had not been of uniform section, the fall would have been proportional to the *resistance* traversed, *i.e.* the curve of the fall of E.M.F. along any conductor is a straight line, the resistance of a conductor, and not its length, being taken as a unit of measure.

From this many deductions may be made, but there are two which claim special attention. The first is, that any number of similar lamps may be placed in series provided that the volts required to be employed with each lamp, multiplied by the number of lamps, equal the pressure between the leads. Thus, two 50-volt lamps, or four 25-volt lamps, may be placed in series upon a 100-volt circuit. The difference of potential between the loops of each lamp being in the one case 50 volts, and in the other 25; the lamps must be similar as regards the current they require, or they will not be worked under proper conditions.

The second deduction is that, if the plates in a battery are put farther apart, the E.M.F. (*i.e.* effective E.M.F.) on the lamp circuit will decrease as the current increases, in a greater degree than when the plates are close

together. These remarks are intended to apply when the accumulator is supplying currents to the mains. This may not be evident at first sight, but the following considerations will make it clear. The greater the distance between the plates, the larger will be the internal resistance of the battery. Again, the larger the current flowing to the mains, the less must be the resistance of that outside circuit. Consequently, there is what, for this argument, may be taken to be a constant resistance in the battery, and a variable one outside; so that the proportion existing between the internal resistance of the battery and the resistance of the outside circuit is a variable one, and this proportion between the battery resistance and the outside resistance becomes smaller as the resistance of the outside circuit becomes less. Hence, more pressure is consumed in the battery as the current flowing in the mains increases, and the remaining pressure to be utilised in the outside circuit is proportionately decreased. These considerations limit, for practical work, the distance which may be given between the plates of an accumulator; because, if they were separated much more than at present, on taking the maximum current permitted for any particular size of section, the fall of E.M.F. would be too great for lighting purposes, and if more cells were installed to allow for this, then the pressure would be too high when few lamps were in use.

As shown by the author many years back, any counter E.M.F. arrangement of low resistance placed between the lines will steady the light when cells cannot be used, such as a motor kept steady by a fly-wheel, or doing constant work.

He took out a series of patents in 1885 for this

method. The specifications show that, not only can a constant E.M.F. be maintained by means of suitably arranged motors, but that they may be used for raising or lowering the E.M.F. as well; in other words, that such regulating motors may take the place of feeders. Like many inventors, he was before his time, and as there was but a very small outlet at that period for their use, the patents, after running a few years, were dropped. Now, however, the system is largely employed, not only in this country, but on the Continent and in America.

It is evident, from all that has been said, that machines with very falling curves regulate automatically and very perfectly; but they are too wasteful in any but very small installations.

In all cases it would be better to look to practical requirements rather than to efficiency. Efficiency is important in a large installation, but in a small one waste is of no consequence compared with the advantages secured by a steady light and freedom from a break-down.

The following simple formulæ may prove of service in making the calculations so frequently required in connection with electric lighting.

Let C = the current in amperes.
„ E = E.M.F. in volts.
„ R = resistance in ohms.
„ $W = CE$ = watts or power.

$$\text{Then } C = \frac{E}{R},\ E = CR,\ R = \frac{E}{C},\ W = C^2R, \text{ because } CE = C^2R.$$

Hence, the waste in a main varies as the square of the current. To give an instance: if the current in a set of mains is doubled, the mains must have their section

increased four-fold, in order that the loss of pressure in passing through them shall remain the same as before.

1 Board of Trade Unit (B.T.U.) = 1,000 watt hours.

746 watts = 1 horse-power.

Therefore, 1 B.T.U. = $1\frac{1}{3}$ horse-power.

1 horse-power (H.P.) = 33,000 pounds raised one foot in one minute.

It must always be borne in mind that a glow-lamp giving the same light, and intended and made to give a stated efficiency, will always absorb practically the same number of watts. For instance, if a 100-volt 8 candle-power lamp requires 0·3 amperes, it would be called a 30-watt lamp. A 50-volt lamp to give the same light would therefore, take a current of 0·6 amperes and be a 60-watt lamp.

An explanation will now be given of the best way to carry out the following requirements:—

First, to make everything automatic; secondly, charging the cells at a constant current; and, lastly, to maintain a practically correct and constant E.M.F. in the house mains.

We have seen that the above results cannot be obtained except by the use of special devices. These wil be considered in their order.

1. The necessary apparatus for putting the current to the cells automatically has been described in Vol. II., but in order to make everything automatic two more conditions are necessary. One is to make the charging current constant by means of a governor; and the other is to have a governor to keep correct and constant E.M.F. on the lines. Maintaining a constant charging current necessitates a variable E.M.F., which, if not governed, is reflected on the lines, and besides this, the

charging E.M.F. is too high for the lamps; for had the E.M.F. of the charging current been made suitable for the lamps, the E.M.F. of the cells would be too low when charging is stopped, unless some were shifted from parallel to series, which would eventually exhaust those cells, and such a method, therefore, is not desirable.

2. To keep the charging current constant, no matter what the counter E.M.F. of the cells may be, and at times when the house leads are being supplied from the dynamo whilst charging, no matter what the characteristic of the machine may be, can only be effected in one way, viz. by altering the E.M.F. at the terminals of the machine in such a way as to produce the desired result. A constant charging current is a great convenience in practice, for, once adjusted, no further attention is ever necessary; and the exact amount of ampere hours put into an accumulator is always known by the number of hours the machinery has run. A constant charging current may be obtained by speeding the dynamo for the highest E.M.F. ever likely to be called for, when giving maximum current—say, for instance, 30 per cent. more E.M.F. than the cells give. Then, by employing a variable outside resistance, which can be placed in the dynamo shunt by hand or automatically, the field may be weakened, and thus lower the E.M.F. The total resistance should be so adjusted that, when the dynamo is giving 10 per cent. of maximum current, the E.M.F. is about equal to that required on the house mains. In this way every possible pressure necessary may be obtained, since, by varying the resistance, every pressure between the limits mentioned may be secured.

For the apparatus to effect these results, see previous volume. It is also possible to insert variable resistances

in one of the leads between the dynamo and cells, but it is a bad method, because it destroys the steadying power of the accumulator and is very wasteful. The resistance also must be varied for every alternation in the current flowing in the lines.

The loss by using resistances in the shunt is *nil*, because, although there is a waste in passing the shunt current (which rarely exceeds 4 amperes) through this apparatus, it is more than compensated for by there being no necessity to reduce the pressure of the main current (which is generally large) after leaving the machine, the actual result being a very large economy.

3. To maintain a constant pressure on the house lines during charging hours, the only practical way is to reduce the charging E.M.F. to the pressure required for the lamps by means of some apparatus put in one of the house leads. This loss by reduction of the E.M.F. is absolutely inseparable from the system, during the time of charging; and the necessary lowering of the pressure can be effected by placing a variable resistance, moved by hand or automatically, in the course of one of the leads: a method which is not good, because the number of steps in the resistance must be very numerous, and the latter must be varied not only with a change of E.M.F. but also for every change of current passing to the house, though the pressure may remain unaltered.

By far the best and simplest way is that which the author devised some years back, viz. by putting counter E.M.F. in one lead in order to reduce the E.M.F. of the charging current for use on the lines. The chief advantage of this system is that only one setting is necessary for a particular reduction, and it is independent of the amount of current flowing. Thus, if the

reduction in the E.M.F. has to be 4 volts, a counter E.M.F. of 4 volts accomplishes it for all currents; but had resistances been used, a different adjustment would have been required for every variation in the current. This method has now been largely adopted. The counter E.M.F. is produced by means of cells like those in the accumulator. A current passing through these cells in the same direction as that in which they would be charged has its pressure reduced at the rate of 2 volts per cell, and a 2-volt jump is not noticeable at the lamps, because the changes are made automatically at the proper moment, and the variations can be limited to 1 per cent. in a 100-volt system. These variations could be effected by hand, but the automatic way is the best. Cells of a different construction could be used to give a counter E.M.F. of 1 volt, or less if desired. Plain lead plates may be employed, with acidulated water for the liquid; and such cells answer very well.

The old method was to place one of the lines from the end cell of the accumulator to some other, so as to include fewer cells between the lines, but leaving the whole of them in the dynamo circuit. Thus the excluded cells give a counter E.M.F. to the house current, which they have to carry, in addition to the charging current. Consequently, if they are not larger than the others, or have shunts, they receive too heavy a current and become injured. In any case the counter E.M.F. method is preferable, and under better control. Besides, every cell in the battery charges and discharges equally. In large installations both methods may be used together with advantage in special cases. In simple installations this excluding of cells is done by hand, but an automatic two-way switch should be employed,

identical with the one used to put the dynamo current to the cells, and worked by the same E.M.F. regulator; only in this case the regulator causes the controlled switch to put one line from the last cell of the battery to some other cell at the same moment that it works the charging switch, and the reverse actions take place on stopping the dynamo. Although two controlled switches are required, they evidently need but one E.M.F. regulator. It is clear that, when much current is flowing in the house mains, the waste is less when the E.M.F. at the dynamo approaches the pressure required for the lamps. The charging current at such times is smaller, and also greater steadiness is secured.

The constant current governor permits of this being done if all the shunt resistance is allowed to be taken out after the dynamo gives a certain predetermined current, effected by proper speeding; and in order to obtain these or other results in practice afterwards, it is only necessary to adjust the governor spring. The various apparatus employed are shown in Vol. II.

If great steadiness of light is required, when the dynamo is supplying the current to the lines, which also gives the economy above mentioned, the governor should be set to make the charging current very small, so that the dynamo may produce very little more current than is being used in the house. The best way to set a governor for this purpose is the following. A second resistance should be placed in the dynamo shunt circuit and worked by hand, which is only to be employed when the above result is desired; and, on these occasions, the resistance is gradually and slowly inserted by hand. The governor then responds by taking resistance out, since it struggles to maintain the original charging

current. Continue putting in resistance till the governor has worked out all its own; after that, every additional resistance put in by hand reduces the charging current. This method saves the operation of continually setting the governor for varying charging currents, which can be done, but is inconvenient to do at a moment's notice; whereas the hand resistance method is very easy, as it may be effected in practice by simply observing the ammeter, which indicates the charging current, and moving the switch handle that regulates the resistance, until the reading is found to be the one required. If it is always intended to work in this manner, it is possible to adjust the governor spring in such a way that the usual charging current is given till house lighting commences, when the effect of taking current to the lamp mains will reduce the charging current proportionally as the house current increases.

One way of securing economy is to charge before lighting hours, and this is best.

Another way of securing economy is to charge at maximum and supply the house at the same time; but if the prime motor is very irregular in its speed, the steadiness of the light is not so perfect as in the manner of working just described. This second method applies to large installations, where, by increasing the work, the machinery is run with greater efficiency. As to which method should be adopted must depend upon the discretion of the user guided by the circumstances.

Another benefit is derived from a counter E.M.F. governor, viz.:—

When the cells are disconnected for any purpose, the dynamo can be used without them on the house mains, since the apparatus governs the E.M.F. perfectly

by reducing all above the normal to the correct pressure necessary for the lamps.

Although, so far, only the advantage has been shown of a counter E.M.F. governor during charging hours, it is evident that the governing action is equally good at other times. Therefore, this apparatus not only protects the lamps from damage during charging hours, and just after stopping, but also secures a steady light on all occasions.

A few extra cells are desirable, for use in the event of the E.M.F. of the battery falling below the normal, should this ever happen. These additional cells are rarely necessary when a battery is properly attended to. The addition of extra cells requires an increased E.M.F. of the charging current, and therefore renders a governor on the house lines the more necessary; but the author has devised a compound switch (shown in the last volume) whereby this increased pressure of the charging current is dispensed with. When the charging and lighting are carried on at the same time, and the method of excluded cells is employed, these cells suffer no injury, which is a considerable advantage; and the extra cells are no longer idle. The method consists in doubling the number of excluded cells and placing one half of them in parallel with the other half. When so placed they form part of the battery, and no longer act as the extra cells. For instance, suppose that the last eight cells are placed four and four in parallel, giving 8 volts; then, by moving the switch, these cells can be shifted to series, giving successfully 10, 12, 14, and 16 volts, or 12 to 16 volts, without intermediate pressures, and all increases above 8 volts are added to the E.M.F. of the battery. In this way the E.M.F of

the battery can be raised 8 volts at any time, with no cells remaining idle; also, when in parallel, and excluded from between the lines (when this method is employed), twice the maximum charging current may be passed without doing injury.

When storage cells are added, or deducted, one at a time, by means of a switch, without breaks, each cell is successfully short-circuited, which causes a large spark on the switch contacts, soon rendering this apparatus unworkable and also spoiling the cells. When two or more cells are included in one shift, the trouble increases. If the short circuit is made through a small resistance, the E.M.F. of one cell being only 2 volts, the spark is very slight, and no harm is done to the cell. If a current is flowing to or from these cells when a shift is made, and the resistance is suitably adjusted, no spark is created. A compact form of switch, meeting the requirements just mentioned, for shifting cells, has already been described in the proper place. It may be mentioned that the resistance to be put between the steps in such switches, when the shift is for one cell at a time, may be a piece of German silver wire six inches long, and of No. 16 gauge.

It has hitherto been supposed that each step of the counter E.M.F. governor in the positive direction increases the counter E.M.F. If storage cells are employed in connection with the governor, then by the addition of a suitable piece of apparatus, instead of the counter E.M.F. being increased at each step in the positive direction, the inverse may also be produced. This extra apparatus or automatic switch must reverse the connections of the cables on the cells end for end. Consequently, if a governor is capable of reducing the E.M.F.

20 volts, with such an addition it could also increase the E.M.F. 20 volts, and its total range would be 40 volts.

This is too refined for practical use, but the possibility of obtaining this large range is shown in the event of its ever being required.

The cells used for reducing the E.M.F. must contain sufficient plate surface to pass the maximum current without giving off large volumes of gas. The size of cells may be chosen by taking double the charging current which would have been employed if they had been used for storage; and this will be the quantity of current which can be passed conveniently, *i.e.* when used for the purpose of reducing E.M.F.

The steps of the counter E.M.F. governor must have no breaks, or the lamps will be extinguished during the shifts.

It may be seen that, when storage cells are used to produce counter E.M.F., they are being charged at such times when a current traverses them.

It should be mentioned that secondary cells, if left at rest for a long period, are not injured when the method of construction employed in the section is good. In this line the writer has made experiments, and cells, which have stood for four years without being charged, were found to be in good order at the end of that time. The only attention required is that the surfaces of the plates should be scratched here and there with a piece of wood or ebonite before recharging the cells, and that the operation of recharging should be done slowly and in accordance with the Rules given in Vol. I.

We have therefore shown that, to get perfect regula-

tion and everything automatic, the following apparatus are required :—

1. An automatic switch to put on the charging current, when the E.M.F. at the dynamo terminals is higher than that of the cells, and to act the reverse way.

2. A governor to keep the charging current constant.

3. A counter E.M.F. governor to maintain a correct and constant pressure on the house lines.

For supplementary apparatus, the following may be placed in the installation :—

1. An automatic switch to exclude a given number of cells from between the lines when charging, should this method be employed.

2. A compound switch to increase the E.M.F. of the battery, by shifting cells from parallel to series, when required, in those cases where extra cells are used.

3. A hand switch, in connection with the constant current governor, to reduce the charging current on special occasions, without resetting the governor, when this method of working is resorted to.

With these appliances, it is only necessary to start and stop the engine, so that a man having no knowledge of electric lighting may be employed. Indeed, the stopping may be done automatically with a steam engine, in the same way as was shown in the preceding volume to be possible in the case of a gas engine, with only slight modification.

The general plan of an installation, with automatic arrangements, is shown in Fig. 23, and speaks for itself.

It may be pointed out that an automatic two-way switch is inserted for excluding 5 or 10 cells, according to the way in which the compound extra cell switch is set. This two-way switch is really not requisite. It

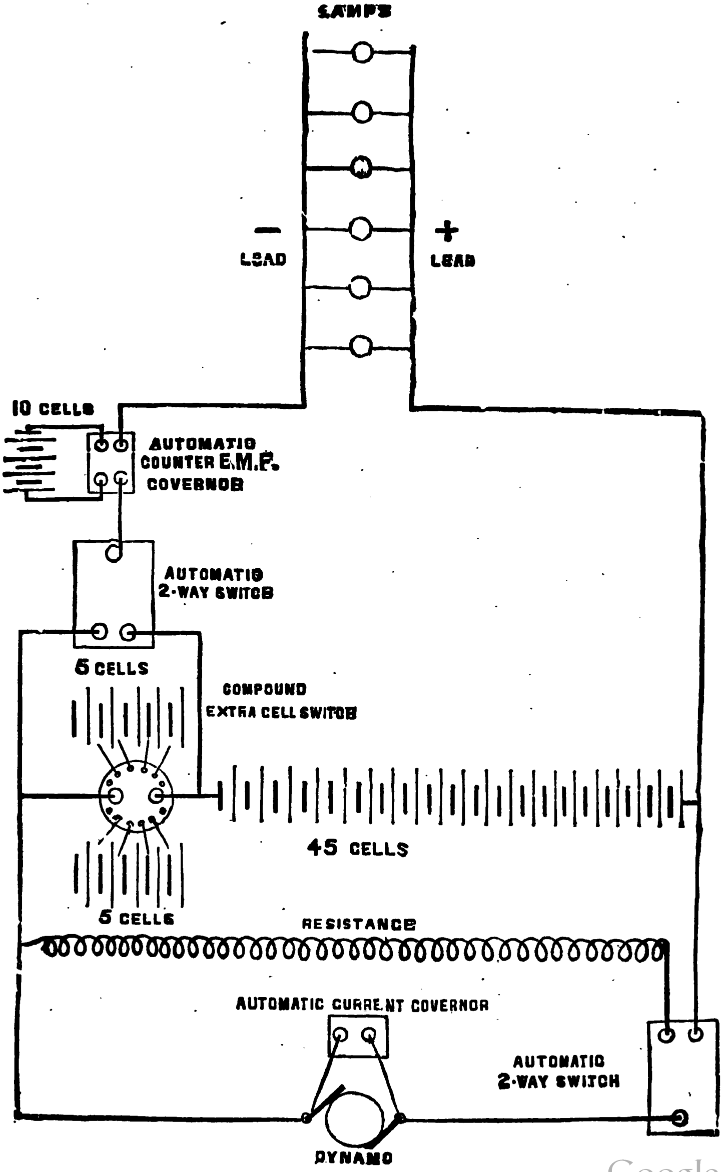


Fig. 23.—Diagram.

would be needed only in the event of repairs being made to the compound switch at any time.

When a gas engine is employed, it becomes a very fair governor for the current, from the peculiar nature of such engines, provided the engine is not too large for the installation, so that often a constant current governor may be dispensed with. These engines tend to run at their maximum power, when the proper load can be given, and in the case of electric lighting this can usually be done, so that the watts given by the dynamo, if shunt wound, are fairly constant throughout a run. The result of this is that, during the charging hours, the counter E.M.F. necessary to keep the pressure correct on the house lines need not be much altered, so that a counter E.M.F. governor might be dispensed with; and all that is required is an automatic switch to exclude a definite number of cells at such times.

But it must be distinctly understood that, when complete governing apparatus does not exist, the charging hours will be very much longer, since the current to the cells diminishes as charging advances; also a constant E.M.F. is absent.

In large gas-engine installations the same governing arrangements are desirable, if not essential, as if steam engines had been employed; in small installations also when the power of the engine is beyond the requirements.

It not unfrequently happens, in small installations, that the E.M.F. at the dynamo terminals falls below that of the cells, in consequence of much current being taken to the house lines before the operation of charging has been stopped. When this takes place, the dynamo commences to act as a motor, instead of as a generator.

The result is, the cells are discharging into the dynamo, as well as to the lines, the gas engine being driven by the dynamo instead of driving it. This is generally discovered by the engine making very few or no explosions, also by the direction of the current as indicated by the charging ammeter. If, when this circumstance occurs, no one happens to be present, the evil continues. The apparatus devised by the author to remedy this mishap has already been spoken of under the name of Anti-Reverser. (See preceding volume.)

In gas-engine installations the engine may be started by using the dynamo as a motor, in which event a starting resistance must be employed, and the brushes pulled over to give a negative lead. The brushes must be gradually moved to the usual positive lead as the speed of the dynamo increases and the engine begins to give explosions.

To bring under the attendant's notice the fact that the cells are charging at too high a rate, should such an event occur, the alarm previously described may be employed.

There is really no need for these excess-of-current alarms, where a constant current governor exists.

When too large a discharging current is taking place, a cut-out acts, and the house is in darkness. To prevent this inconvenience, an automatic arrangement could be added to the installation. The device would be as follows: When too great a current leaves the cells, a special form of two-way magnetic cut-out works, putting a large resistance into the circuit, thereby reducing the current. When the current is brought within the proper limit, the resistance is automatically removed. What would happen in the house would be

this. When too many lamps are put on, the light of all of them would suddenly fall, but they would not be extinguished; on reducing them to the permissible number, their brilliancy is restored.

The details of two first-class governors have already been explained in Vol. II. Therefore, they need not be entered upon afresh.

It may be truly said that for want of proper governors, or through some other reason, few installations really work perfectly in all respects.

A few special ways of working an installation may be mentioned.

It sometimes happens in a small installation, where a gas engine is in use, that the dynamo and cells are both giving current to the lamps, and, under these circumstances, the light is frequently unsteady. The reason is that, under such conditions, the E.M.F. of the dynamo and cells is equal or nearly so; and since every irregularity of speed, which is considerable with gas engines, produces a rise or fall of E.M.F. at the terminals of the dynamo, the cells are at one moment giving all, or nearly all, the current to the lines, and perhaps even making a motor of the dynamo, and at the next the dynamo is giving all the current, and also possibly charging the cells at a very low rate. Consequently great strains are given to the cells and dynamo alternately, and the engine runs far worse than it would do in general.

The case given is supposed to be a bad one, but the difficulty occurs in many degrees. A very simple remedy is the following, when a large number of lamps are required to be used at one time. Disconnect the shunt wires from the brushes and connect them to

the cells, so that the cells are discharging the whole evening into the shunt circuit. Such a current rarely exceeds three or four amperes, so that a constant field is obtained for a very small loss of charge. The lines also must be disconnected from the cells. The dynamo now gives all its current to the lamps, including that which usually goes to its shunt circuit. Thus the machine is made to give, without strain, more than its nominal output. This is the very best way to work when the utmost power of an installation is needed, especially if the dynamo has a capacity equal to, or greater than, the maximum discharging rate of the accumulator. Even with smaller dynamos, this mode of working has many advantages. Naturally the changes of connections would be done by means of switches. It should be mentioned that a dynamo ought to be large enough to produce the utmost current required in the lines and to charge the cells at the same time. In the long run this is an economy.

Another method, whereby the light would be quite steady if all arrangements have been well devised, is that of working at "balancing point," when the two steadying properties of the cells come into play. To work in this manner, the current flowing in the lines must remain constant, or the equilibrium will be lost. An experimental run will soon decide how many lamps must be on in order to arrive at the required condition. From the remarks made in Vol. I. on the undesirability of charging the cells with very small currents, it might be thought that to work on balancing-point method would injure the cells, but in practice the method of working here described can produce no injury, because it is only for short periods that these small currents

traverse the accumulator. Ordinary charging will naturally be resorted to, as usual.

In practice, the work done by the counter E.M.F. governor is this. As charging proceeds, cells are put in, one by one, in the course of the day; and on stopping, the majority are taken rapidly out. Those remaining are removed from the circuit, one at a time at intervals during the evening; and when the cells give a good E.M.F., a few are put in again, after the lamps are extinguished, in the course of the night. The motor, therefore, does not run more than a minute a day at most. Such arrangements remove all anxiety, break-downs become practically impossible, and a steady, good light can be obtained at all hours.

Although it is a somewhat difficult matter for anyone to describe the general working of a complex arrangement, yet it is easier for a writer to give an account of what he already knows than for a reader to follow a subject that is altogether new to him. In order, therefore, to show at a glance what actually happens in an installation which contains an accumulator and automatic arrangements, the diagram shown in the frontispiece is given. This is a photograph of a double chart, taken at Broomhill, with a Richard's registering ammeter and voltmeter combined. (See Vol. II.) The irregular line on the upper chart shows the voltage, and that on the lower one the current. To obtain the voltage at any moment for the current reading, one has merely to cast the eye down vertically. It should be pointed out that there is an error in the volt chart; where the line appears just under "110" it should be under "100," the needle having become accidentally set to the former instead of to the latter. Here and there along the volt

line will be observed a little vertical line: each line indicates the moment when the counter E.M.F. governor worked, and the result is produced simply by the swing of the pointer which carries the pen, and not by an actual alteration in the voltage. On the lower chart upon each day there is a kind of smudge: this indicates the time during which charging proceeded. The actual curve should run about the centre of the black patches.

The cause of these thick marks is that the pen swings during the charging, notwithstanding that glycerine dashpots are employed; and as the cylinder revolves very slowly—once in fourteen days—the swings of the pen draw the lines so close together as to give the appearance of a blot. On the original chart it is easy to observe what the true current is, because the lines are not as close to one another as they appear to be in the reduced photograph.

There are no special remarks to be made on the volt diagram, but on the other some interesting points call for notice. On Sunday, at the left-hand side, it can be seen that the cells were charged for about two hours with about 73 amperes. In the same manner the duration of the charge may be observed for the other days of the week. On Thursday the charging was proceeded with twice. The engine-driver went to his dinner soon after noon, and for some reason or other he did not start again till half-past two o'clock. On reference to the volt chart it will be seen that every time the charging is started the counter E.M.F. governor worked to lower pressure on the house-lines. Consequently the pressure-line is fairly even, notwithstanding the great variations in the engine-house. On looking at the lower portion

of the ampere-chart there will be seen the current which has been used in the house and elsewhere; and it will be noticed that a small amount of current was used between eight and ten o'clock in the morning, since the diagram was made in the month of December when the days were dark; that the lighting-up of the house began about five o'clock, or rather earlier; and that all lights were out at about midnight. On Saturday, it will be observed, a great deal more current was used at the house than on any other day. In fact, on that evening there was a dinner-party, as well as staying visitors who apparently did not retire until nearly two o'clock. On the Sunday following the cells were charged a much longer time than on the preceding Sunday, in order to make up for the larger amount of current taken from the cells on the previous evening. Such a diagram is very instructive, since at one glance it gives the whole history of the working of an installation.

Duplicates, clutches, and other complications may be completely dispensed with, excepting in those cases where the installation is very large, and more than one dynamo is required to do the work.

It is possible, when the E.M.F. is just high enough to charge, to construct an apparatus to put the dynamo to the cells, by differential action, *i.e.* difference in E.M.F. between the dynamo and cells. These instruments are very sensitive, and might prove of service in small gas-engine installations; but in other cases there is not much to be gained by their use. These apparatus have been described in the preceding volume.

When the variations in the speed of the engine are very great, say over 10 per cent., and sudden, no governor will meet the difficulty by itself, on account of

magnetic momentum. In such cases a very loose belt will often enable the governor to do the work required of it, by means of "slip." If this is insufficient, the dynamo pulley may have a rachet or roller clutch within it, permitting the armature to run faster than the pulley at any time. The clutch described under "Apparatus" is the best cure and a certain one.

When a constant current is required, a constant-current dynamo meets the difficulty, which is only likely to occur when the electric light is driven by an engine running machinery direct, without motors, at the same time.

A complete arrangement of automatic switches and governors is shown in Figs. 24, 25, 26, and 27. These are reproductions from photographs. This stand of governors was arranged by the writer to send to an Exhibition of Electrical Apparatus.

Fig. 24 is a front view. At the top is the counter E.M.F. governor. On the right and left of this are the end views of the E.M.F. and current regulators. Below the E.M.F. governor is seen the constant current governor with the motor automatic switch on one side, and another form of E.M.F. regulator on the other side. Below these will be observed the motor which works the governors and the automatic two-way switch. These various apparatus have been described in Vol. II.

Fig. 25 is the same group of apparatus, seen from one side.

Fig. 26 the same, seen from the other side. In this illustration the automatic switch is well seen.

Fig. 27 shows the back of the apparatus with the cable terminals.

Fig. 28 is the diagrammatic view of the connections. The whole of these the reader may trace without

difficulty, if he has understood the principles detailed in this chapter.

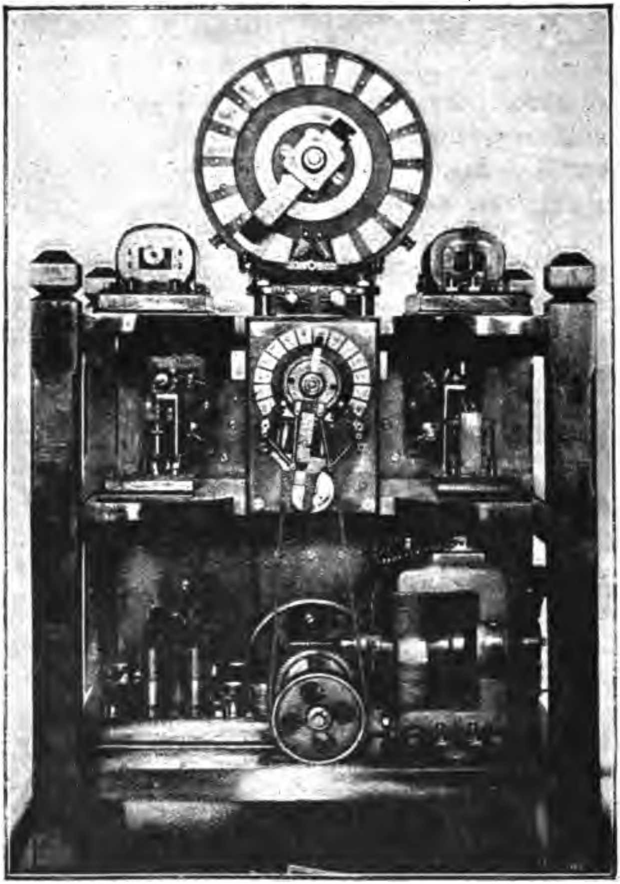


Fig. 24.—Governors. Front View.

There is a condition of things which may almost be described under the name of a gas-engine paradox.

Under certain conditions a gas engine will make

maximum explosions, and run below normal speed when producing a given current. Hence, if a larger current is

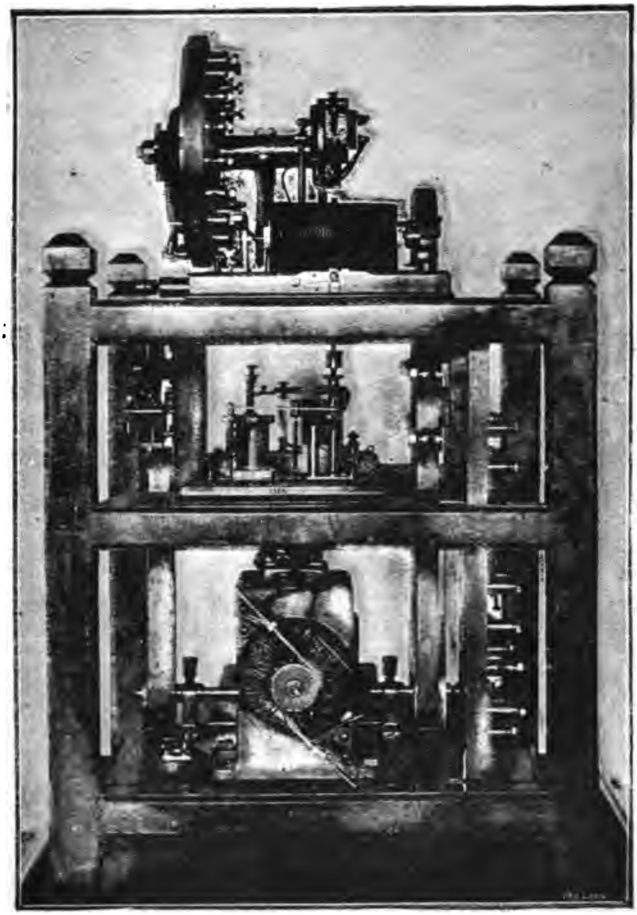


Fig. 25. - Governors. Side View.

wanted, and the resistance of the circuit lowered for this end, the engine will run still slower and produce no

more appreciable current; in short, any small increase

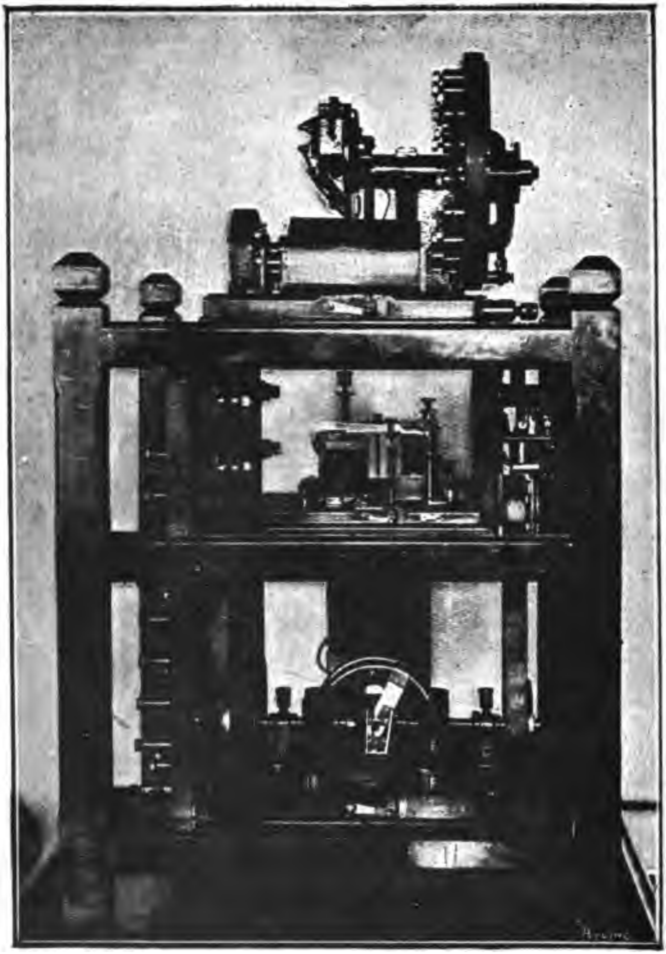


Fig. 26.—Governors. Side View.

in the current tends to pull up the engine. The engine is then declared not strong enough for the work. The

following method appears to raise its power, although in reality the desired result is simply attained by running the engine under more favourable conditions. If re-

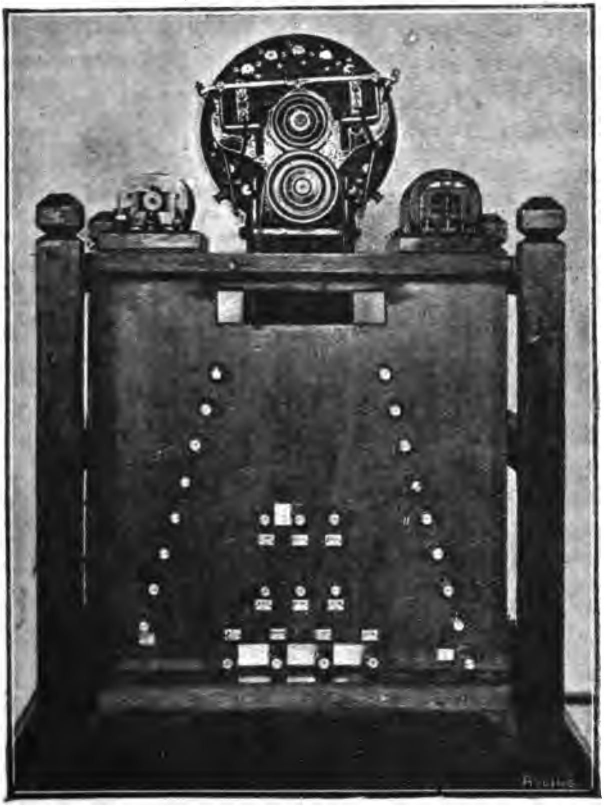


Fig. 27.—Governors. Back View.

sistance is placed in the field-magnet shunt-circuit, it will be found that the engine runs faster and therefore delivers more power. The current production, which appeared at first to overpower the engine, will remain

almost the same, or will somewhat increase; not only is this result attained, but a still larger current may be produced if required. The engine will now work with comfort. Resistance may be added to the shunt until the maximum speed of the engine is reached, and such resistance will not be found to impair the magnetic field; for the speed of the armature will increase in proportion to the resistance added.

This apparent paradox may be explained in a simple manner. The power delivered by the engine is virtually proportional to the gas used by it; hence, if the engine can be run at a greater speed, more gas will be consumed in the same time, and consequently more power will be delivered in a given time. Many a gas engine has been condemned and exchanged for a larger one on the ground that it was too weak, when the knowledge and application of the above resource would have set matters right.

A few points may again be mentioned in regard to motors, since they are of great importance.

1. Always remember when starting a shunt motor to lift a brush, or to do the equivalent by means of a switch, in order that the field magnets may become excited first.

2. It is best to employ series-wound motors, as they can be started with more ease.

3. Except in the case of small motors, which only require from 1 to 3 amperes, start gradually with a resistance by means of a step-switch.

4. A short belt, to connect the motor to the machine it runs, is a better way in practice than direct or rigid connections.

5. If at any time the magnets fail to excite, as in

the case of dynamos, a few taps with a hammer on the yoke will rectify the difficulty, should everything else be in good order. When the current will not start, a piece of iron brought near the field magnets to test the mag-

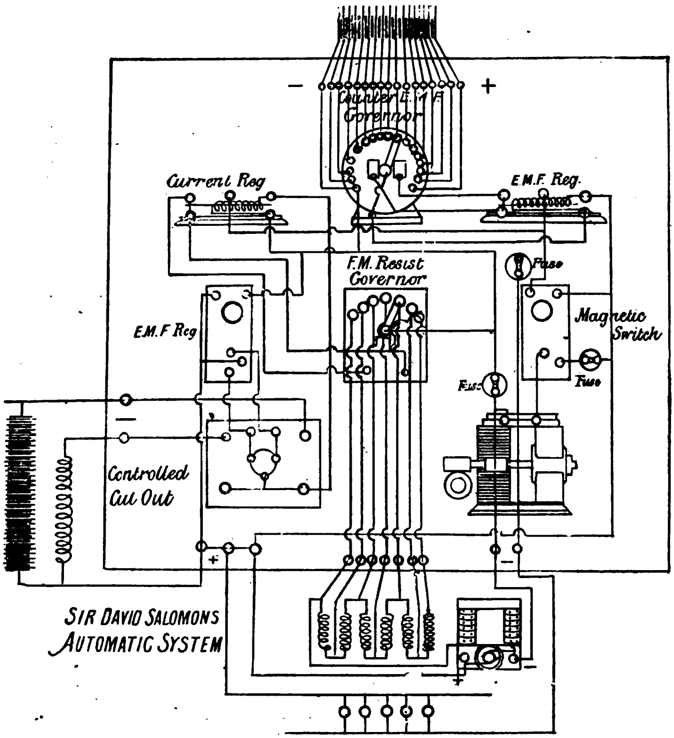


Fig. 28.—Author's Automatic System, Diagram.

netism will always decide whether the magnets are excited.

When a house is supplied from a public source with direct current, great saving in lamps will be effected if a counter E.M.F. governor is employed with say, two

or three cells. In this event, hand regulation is good enough for the purpose. By using this apparatus, the writer has saved the money it cost, many times over in the course of twelve months, by economy in the use of lamps.

When the supply is a current of the alternate type, a governor may also be used, but of a different construction. At one time the author was supplied with such a system, and the number of lamps destroyed far exceeded in value the bill paid for the current. This was completely remedied by using Mr. Kapp's Regulator Transformer, which is shown in Fig. 29 (from *Industries*, April 12, 1889).

This apparatus consists of a transformer, which is in connection with the secondary circuit, the thick coil upon it being placed in the course of one of the leads. The current enters the apparatus by the cable B B, which comes from the secondary circuit upon the Company's transformer. This cable is attached to the contact ring C upon the switch S. It then passes through the finger and onwards to the thick wire coil upon the regulating transformer, leaving the apparatus by the cable D A A, which passes to the distribution board or elsewhere. The thick wire coil upon the regulating transformer is divided into sections; and these are in connection with the contacts of the switch S, which enables the current to be sent through one or more of these sections which, as already mentioned, are in series with one main. These sections are all joined together upon the transformer so as to form one coil. The fine wire coil upon this transformer has a high resistance and is placed across the mains by means of the wires *a b*, which are attached at T_1 T_2. One of these wires has a switch in its course, *s*.

The results are that, for every section of the thick wire coil introduced into the circuit of the house-conductor in connection with it, the E.M.F. on the mains is raised

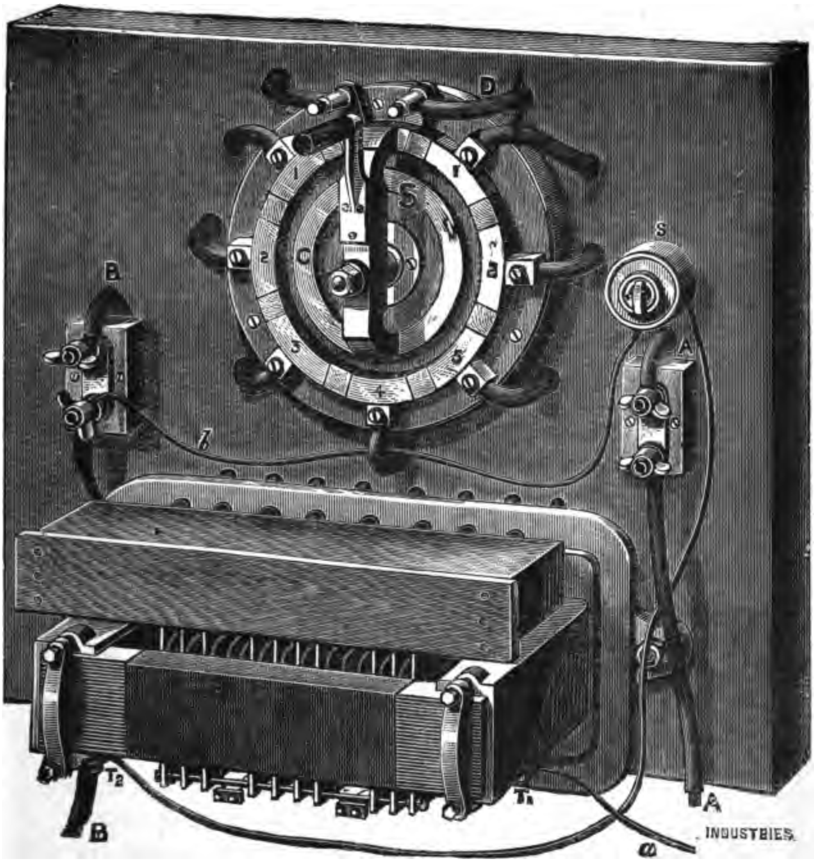


FIG. 29.—Kapp's Regulating Transformer.

2 volts; and since there are five subdivisions of the coil used for this purpose, the pressure can, by successively moving the switch finger over the corresponding five

contacts marked 1 to 5 on S, be increased up to 10 volts by 2-volt jumps. There are yet two more sections of the thick wire coil in connection with contacts 1 and 2 (right-hand side) upon the switch, and on these the switch finger can only be placed after passing its zero position, since there is a stop-piece between contacts 5 and 2. The arrangements are such that, when the current is permitted to pass through these two sections of the coil, its direction is in the reverse way to that when it passes through the other ones mentioned. Consequently, instead of a rise of 2 volts per step, there will be an equivalent fall in the pressure. In this manner, if the E.M.F. on the house mains should rise too high, it may be lowered. Since the drawing was made, the switches S *s* have been replaced by one switch specially designed by the author. Its description is as follows: The switch-finger is divided, with a small resistance placed between each half, enabling the shifts to be made without cutting off the light or burning the contacts. There is also a special form of snap-action to ensure the finger assuming its proper position. Combined with this switch is a second one, and so arranged that when the main current is turned off from the transformer, the thin-wire circuit is cut at the same time, and a small waste of current, which would pass at such times, amounting to nearly two amperes, is in that way prevented. The practical result of the apparatus is that it can convert amperes into volts. When employed for reducing pressure, it consumes a certain amount of power also. This may appear a paradox. But it must be remembered that, when the pressure of the house current is lowered, a less amount of current passes through every lamp; and, theoretically, as well as prac-

tically, the whole of the saving should be found from this result. Under no circumstances or conditions can a transformer produce strictly theoretical results, for there are losses of energy, though not very great, in this apparatus, as in all other machines. There is another small automatic apparatus, in connection with this transformer, which breaks the thin-wire circuit in the event of the pressure on the house-mains circuit rising beyond 100 volts. This cut-out consists of a solenoid, which draws into its centre an iron core which is balanced by a spring. This core discharges a switch at the proper time. By means of this automatic instrument the lamps at times are saved, *i.e.* if the pressure had been raised 6 volts, and if the E.M.F. on the secondary mains were to rise, say from 92 to 98 volts, the lamps would be worked at 104 volts (that is, 98 + 6), which would injure or break them. But the fine-wire circuit would be cut at the moment that 100 volts were reached, destroying the action of the regulating transformer, and averting the injury, since the current passing through the thick wire upon this transformer does not raise its pressure, excepting at those times when a current is passing the fine-wire circuit.

The remarkable properties of transformers come into play in this particular instrument as they do on other occasions, *i.e.* the current through the fine wire increases in proportion to the increase of current in the thick wire. This regulating transformer could only be used in connection with alternate currents, and analogically replaces the counter E.M.F. governor employed with direct currents. Such a regulating transformer, with an ordinary kind of switch, costs about 25*l.*; but with the improved switch and automatic arrangement, about 10*l.*

more should be added to the cost. The price is mentioned in order to give information to such persons as may be on alternate current circuits and desire to test the great convenience this instrument offers. The insertion of such an apparatus is not unfair to the Supply Company, because the extra current consumed is measured upon the meter, if there is one; and when this is absent, the consumer is only obtaining the pressure at his lamps for which he contracted. When the measurement is by meter, the Supply Company ought to allow a reduction in the payments for current produced below normal E.M.F., because the current used in this transformer is simply that necessary to give the pressure which should have been supplied, unless the meter registers energy. A meter in the course of the fine-wire circuit would measure the deficiency. The arrangement presents another advantage, which is of importance even when a regular and standard pressure is given. At those times when a more brilliant light is required, this may be done; and on other occasions, the pressure may be somewhat lowered. In that way the lamps may be given a much longer life, without the disadvantage of obtaining this end by inserting lamps of higher volts throughout the installation; which would not yield as good a light as would be produced if the proper voltage lamps had been used, and besides it is an inefficient proceeding. Also, the wiring in the house may be of a smaller section (of course not unduly so); and this saving in cost would in many cases more than cover the expense of the apparatus, without increasing fire risks.

It may be pointed out that, if in any house supplied with alternate current and using a Kapp's Regulating

Transformer, in the event of a change being made to direct current, a very good hand regulation can be secured by replacing the transformer with a few secondary cells; the switch and other arrangements which were in use with the transformer being equally applicable for the cells. But automatic regulation can be obtained only by the methods described in connection with self-acting apparatus.

The distribution of electrical energy by means of direct current is not so simple as with alternate current, the apparatus for this purpose being more complex than the transformer. Reduction in the pressure of direct currents may be effected by means of storage cells, voltameters, and special motors, called "direct current transformers;" these three methods being equivalent to an extended three-wire system. The chief disadvantage attending the use of alternate current is that no storage system exists in connection with it, except of a very complex kind. The current must be converted into a direct one before storing. Many public installations have been recently started, using direct current combined with accumulators. A few years must elapse before the vexed question is settled as to the comparative merits of the two systems of alternate currents and direct currents; also as to whether both systems may not, under special given conditions, be beneficially employed with advantage.

Fig. 30 gives the three appearances of the E.M.F. curves of direct, alternating, and re-dressed alternating currents respectively. In all three diagrams it will be noticed that the horizontal line indicates zero. In the upper one there will be observed the E.M.F. curve of the direct current: the E.M.F. is always above the zero

line. In the middle diagram, for the alternate current, the curve passes through the zero line to the negative side ; and in the re-dressed diagram, the lower one, all the pressure is above the zero line, although at certain points the pressure of the current reaches zero. Consequently, a re-dressed alternate current is not quite the same thing as a direct current, though for all purposes but one it may be employed in the same way ; that

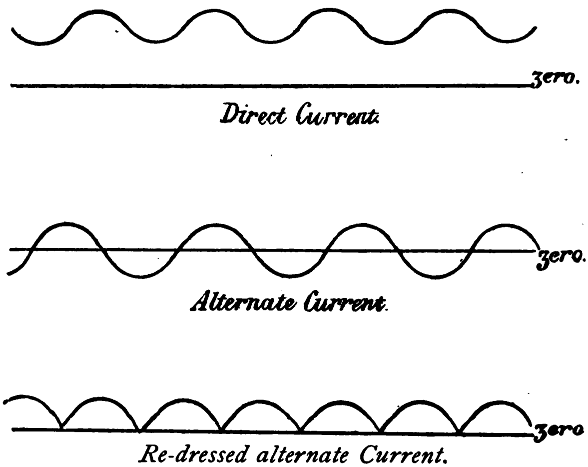


Fig. 30.

exception being to charge accumulators, since moments will occur when the E.M.F. is zero. Apparatus have been designed for cutting off the current at the moment when it approaches the zero line, in which case a re-dressed alternate current can be used to charge an accumulator. As at present made, the apparatus is too complex for general service.

Arc lamps, using a re-dressed current, do not form a typical crater.

If two or more alternate currents are combined so that their phases do not coincide, what is called a poly-phase current results. Such currents can be employed with great advantage for motors and for many other purposes. There are very pretty polyphase motors made at the present time, but since these currents are not supplied by any public company they are not brought into practice in this country. In some places abroad they are used on a large scale.

Many persons cannot see why the tides should not be employed for the production of electric energy. Millions of horse-power are wasted daily because man-kind is as yet unable to bring this force under control. It is advisable to point out the reason why. The power of the tides probably will never be utilised for a useful purpose on a large scale. The power de-rived from water may be defined as a given weight of water falling, by gravitation, through a certain distance. If the average rise of the tides is, say, 20 ft. (it varies enormously at different places), then the utmost fall will be 20 ft. It is evident that, although the upper surface of the water may have been raised 20 ft., the average is only half that, viz. 10 ft. Consequently a given quantity of water, which has been raised 10 ft., must fall through that distance before the next tide begins to rise; which, taking an example in a rough way, means that a given area of land must be flooded during the rise of the tide; and the whole of this water must be let out, in the course of a few minutes, at low tide, once in about every six hours. This method of utilising the power is in itself a great difficulty, but to obtain land at suitable levels and sufficient extent for the purpose, or to attempt to excavate the ground so as to bring it to

the correct level, is quite impracticable, for land has a value, and labour, too, has to be paid for. If, in ancient times, when forced labour existed on a large scale, the people who attempted to build the Tower of Babel and the Egyptians who wasted their energy in raising the Pyramids, had combined to flood the desert of Sahara, which is said to be below sea-level, their united efforts in that direction would have proved a benefit to mankind at the present day; and it is to be regretted that no one had sufficient foresight in those times to discern what Science might achieve in the future.

There are advantages connected with electric lighting which are frequently overlooked. For public lighting, the chief advantage, apart from any other consideration, is a large economy apparent in the fact that, at one moment, and at any required time, the whole of the lamps may be lit or extinguished. No one can have failed to remark what a large number of gas lamps, at present used for public purposes, are lit in broad daylight, and how many remain unextinguished after daybreak. There is also the difficulty of lighting street lamps when a fog comes on suddenly. All this is due to the fact that the number of men employed for lighting up being limited, naturally they cannot do the work, whether of lighting or extinguishing the lamps, instantaneously. When there is an electrical system of public lighting, the whole of the lamps can then be lit and put out simultaneously at any given moment, without extra labour. This has been well proved in the case of the City of London, and elsewhere.

For private, no less than for public users, there is a decided advantage in favour of the electric light, when illumination is required in the open air; as, for instance,

in the case of a garden party, for illuminations and temporary work. Then the common enemies—namely, wind and rain—to the ordinary sources of illumination have no power. The same remark will apply to fire, of which there can be no danger, provided ordinary care be exercised in the placing of the conductors.

In connection with the electric light there have been numerous fires and other accidents; but these, in every instance, may be traced to bad work or carelessness, so that users of electricity need have no fear if only they employ competent people, and do not grudge money to secure the safety of life and property.

There is a peculiar circumstance which should be noted. If an arc is set up at any portion of a circuit in the course of the mains—such, for instance, as a fuse melting and creating an arc across the terminals, which may occur with a high-pressure system—then the E.M.F. throughout the circuit becomes enormously raised, which is probably due to some resonant effect being set up owing to the oscillatory nature of the discharge. Great attention, therefore, should be given in all cases where there is any chance of such a circumstance happening by employing fuses which will not produce this effect, and attention should be paid to main switches—other matters also—or the probability is that the alternators or dynamos will be injured by the insulation of their windings being pierced.

It is, perhaps, desirable once more to convey a general idea of how a dynamo, or an accumulator, works: for so many persons appear to have a difficulty in realising that the power absorbed is only proportional to the current taken, and that in the case of cells these will give only the current actually required from them,

depending in both cases on the resistance of the circuits. The best way to bring the real state of facts to the mind is to regard a dynamo or a battery as a tank containing water under pressure; for it is quite evident that, so long as no water is drawn from the tank, there can be no loss, and, further, that the amount of water so drawn depends on the degree to which the tap of the tank may be turned on. In this case the opening given to the tap is comparable with the resistance of the outside circuit.

The experience of many years has shown the advisability of employing gun-metal in preference to brass for electrical fittings exposed to moisture and the open air, and for the London atmosphere. Brass is an alloy of copper and zinc. Moisture and the air of cities dissolve out the zinc, leaving the copper of the alloy in the form of powder, which becomes green by reason of a partial conversion into copper acetate. To put this in general language, it may be said that the brass rots. Gun-metal consists of tin and copper. Tin, not being readily oxidisable when mixed with copper, appears almost entirely to resist the action of moisture, so that this alloy may be regarded as everlasting, in the human sense of the word; especially when it is remembered that bronzes of the ancients are still in existence, having suffered but little by corrosion. The cost of gun-metal is nearly double that of brass, but the amount of labour expended on an article made in either material is virtually equal; so that in practice it might be expected that small fittings, whether in gun-metal or in brass, cost about the same; and in heavy articles it would not be much greater. This surmise has been proved true by actual experience. In all exposed situations a thick coat of shellac varnish proves an admirable protection. Fittings

in stables must be carefully protected against the ammonia vapour which exists in considerable quantities in such places. Thick coatings of shellac is, perhaps, the best method to employ.

Two new alloys have recently appeared: one manganese steel, and the other manganin. The former is practically non-magnetic, while the latter is nearly allied to platinoid in the sense that it has a very high resistance, and for various temperatures the resistance remains almost unaltered.

The possession of a non-magnetic watch is almost an imperative necessity to those whose work brings them constantly into the neighbourhood of dynamos and motors. Although a considerable demand exists for such watches, and large numbers are sold under the name of "non-magnetic," it is remarkable how few of them have the requisite qualities. Most watchmakers deem it to be sufficient to construct a watch which, if brought near a dynamo, is not stopped by the action of the magnets. But this is not an adequate test. Unless the watch may be turned round slowly in every possible direction, in close proximity to the magnets and at various parts of them, the test is imperfect. There are very few non-magnetic watches that have passed through the hands of the writer which have not stopped when such a test is applied. It may be mentioned that the lever escapement is the easiest and best form of movement to render non-magnetic. The steel hairspring is replaced by one made of palladium. The lever and the scape-wheel should be of phosphor bronze. In the better class of watch the lever may have ruby pallets, and the balance should be of hard gold. If the balance is a compensation one, two suitable metals must

be selected, neither of them being steel—possibly manganese steel would answer for one. The cylinder escapement cannot be rendered non-magnetic in any satisfactory way. If an ordinary watch becomes magnetised, it either goes very irregularly or will not go at all. Some watches, although they may go fairly when magnetised, on approaching a dynamo or motor, stop and then start again when no longer in proximity with these machines. In such cases the watch will be slow in point of time. Nothing is more simple than to demagnetise watches of ordinary construction : it is only necessary to have a solenoid large enough to enable the watch to pass into the centre. An alternate current should be passed through this coil, and the watch slowly let down into the latter, then slowly raised again, and gradually moved away from the action of the coil. The magnetic reversals produced in the steel, contained in the watch, demagnetise the metal. A very suitable coil for the purpose is one with a resistance of from 15 to 20 ohms, about 4 inches high, and the hole 3 inches diameter; the wire having a sufficient section to permit of its being joined to a 100-volt circuit.

It is of great importance that the snap-action in a lamp switch should be very perfect and certain, so that by no possibility can it be left half on, or in an arcing condition, *i.e.* so that the spark created on cutting shall continue. The arc is broken, if the finger moves through a sufficient distance. This result is brought about by the snap-action or its equivalent, and the possibility of fire is guarded against.

When alternate current is used there is a very simple way of lowering the light of a lamp. Holders are made containing a small choking coil, and the switch upon

this holder has many steps. The arrangements are such that the light given to the lamp can be raised or lowered, according to the position given to the switch. When a lamp is to be used simply as a night-light, the illuminating power can be rendered as small as may be desired by inserting permanently a resistance in series with it. This can be placed near the switch or at any other convenient point. Sometimes a lamp may be used as the resistance; when intended to lower the voltage it is, as a rule, most suitable; but such a lamp, in order to screen any light it may give, must be enclosed in a fireproof case, such as metal or asbestos, and should be well ventilated.

When the current is paid for in the same way as gas, it is a good plan to place a check upon the persons left in charge of the house when the family is away. With gas this cannot be done except with a "penny in the slot" apparatus. With the electric light nothing is simpler: the method is merely to reduce the size of the main fuse. The following plan has been adopted at the writer's house in Grosvenor Street. Two fuses are placed in parallel in one of the house mains, one melting with 90 amperes and the other with 10, so that when both are in use they are equivalent to a 100-amperes fuse. The 90-amperes fuse can be cut out by means of a switch. When the family leaves town, it is only necessary to turn off the switch; and any current exceeding 10 amperes will place the house in darkness, this quantity being considered sufficient for all ordinary purposes. The method of replacing the fuse is simple and convenient. The switch and 90-amperes fuse are placed in a glass case, locked up. Outside the case there is one of the author's universal connectors,

the plug portion being modified to form a fuse box. In the event of a renewal being required, spare plug boxes can be inserted. The arrangement of this box is such that the fuse can be seen through a glass pane. It is also impossible to remove the fuse-box cover or replace the fuse without removing this box completely, so that no accident can possibly occur by servants or others playing with it; and the most obtuse individual can see if the fuse has melted and can replace a new fuse box ready charged, a few spare ones being left for that purpose.

If lamps made for use with a given E.M.F. have a current passed through them of greater pressure, the globes will be rapidly blackened, and the lives of the filaments shortened. Should this pressure be too great, the filaments will be broken; but, provided the extra E.M.F. does not exceed 5 per cent., the lamps will last a considerable period, and their light-giving power will be enormously increased above the normal. On the other hand, if the pressure be below the normal to an extent so small as that of 2 per cent., their lives will be three times longer, or even more, than that given by the makers, who generally place the period at 1,000 hours. The globes, moreover, will blacken but very slightly from the beginning to the end. Their light, however, will be considerably below that intended to be given. Upon these facts a question of importance naturally arises: Is it more economical to burn the lamps at a lower efficiency so as to require renewal less frequently, and employ more of them to obtain the required light, or at a higher efficiency with fewer lamps and more frequent renewals; in other words, is it better to use a lower or a higher E.M.F. than that intended for the

lamp? This can be answered by obtaining an equation, its elements being determined by experiment. Professors Ayrton and Perry have attempted this, others also have given their attention to the matter; but these gentlemen have considered the question from a purely mathematical point of view. Consequently, their conclusions should be correct, provided that their experimental data are accurate. The author's solution of the problem, based on a large number of actual tests carried over hundreds, and in some cases thousands, of hours, point to the inference that, in the present state of lamp manufacture, the best efficiency to be obtained is that of employing an E.M.F. 2 per cent. above the normal, as indicated upon the lamp. He himself prefers a pressure 1 per cent. below the normal, for the reasons following. The duration of 100-volt lamps under this condition exceeds 3,000 hours; the light emitted is not as white (which by many people is considered an advantage), and the trouble of renewing lamps becomes a nominal matter; lastly, the loss of light, through the globes becoming darkened, is very small.

Glow lamps may be placed close to tapestry, ceilings, or inflammable substances, provided they are not in absolute contact, which would produce a slight charring or discoloration. Even if the glass globe breaks, there is no danger from fire, because the heated carbon filament, in the presence of the oxygen of the air, becomes immediately converted into carbonic acid gas; *i.e.* on breakage occurring, the light is extinguished by the instant destruction of the filament. It must not be supposed from this remark that the whole filament necessarily disappears. If any part of the filament is weaker than the rest, it will naturally go first and the circuit will be cut,

so that any portion of the filament remaining will no longer be acted upon by the oxygen, since it has lost its high temperature.

Several tests were made on a number of 100-volt 16 candle-power lamps to discover the actual light given at different E.M.F.s. With similar lamps there were slight variations for the same E.M.F., so that in giving the results round numbers may be employed. They are as follows. For 102 volts, the candle-power was 19; 101 volts, 18; 100 volts, 16½ to 17; 99 volts, 13½; 97 volts, 12; 93 volts, 8. Obscured lamps gave a loss of light of between 16 to 17 per cent., but produced much greater diffusion.

Dr. Hopkinson finds that an 8-candle lamp gives about the same light as an ordinary 5-foot gas burner. This test agrees very closely with that made by the writer.

No part of a fitting should be used in place of a return wire. All wires passing into and through fittings should be well insulated.

In residences, the socket lamps which fit in holders are by far the best to employ, since any ordinary domestic can replace a lamp with the greatest facility. It is necessary to observe that the spring contacts in this class of holder are of sufficient length and strength to ensure a perfect contact when the lamp is inserted. Otherwise considerable heating will take place, which may lead to the destruction of the lamp and holder. If this attention has been given in the first instance, no further care is required.

Loop lamps are probably the best to use in places subjected to considerable vibration, since the contacts are more certain and firmer, but more care is needed in attaching these lamps.

A question is frequently asked by unscientific people: Is there any waste when a lamp is turned out? The answer, of course, is in the negative.

Many of the above remarks are repetitions of what has been said elsewhere, but the points are of such importance that it was deemed desirable to make a *résumé* of them in this place.

Numerous little points which may prove of interest to many who read this book will be touched upon. Although apparently insignificant details in themselves, they are important in many ways. In the previous volume a chapter was inserted on Practical Applications. But in most instances the apparatus were suitable to connect directly with the house circuit, which is usually 100 volts; this pressure having been adopted universally in this country for domestic purposes. Any other pressure in use may be regarded as only remnants of the past. Frequently it is desired to charge small cells, which are intended for portable lamps, medical purposes, and other requirements. All that is necessary is to know what current should be passed through the cells in order to charge them. As a rule not more than three or four cells form the set, so that they cannot be connected with the main circuit on account of the small counter E.M.F. they offer, as well as having a very low resistance. Attention must be given so that the right polarities may be joined to the cells; positive to positive, and negative to negative. Then a lamp is placed in series with one of the charging wires, such a lamp as would be suitable for the pressure of the house mains, and of such a size that it will pass the charging current of the cell or cells. For instance, let it be desired to charge two small cells at the rate of one

ampere off 100-volts mains, a 16 or a 25 candle-power 100-volt lamp, placed in series, will be the correct resistance to use. For those who often have to charge small cells, it will be found convenient to mount on a block of wood a lamp-holder, the wires to these being brought to two terminals; so that the lamp-holder may be placed in one of the charging leads, and, according to the current required for charging, the suitable lamp will be put into the holder.

When a phonograph, as at present made, is connected with a 100-volt house circuit, a 100 candle-power 100-volt lamp is the right resistance to use. Failing this, a resistance frame of 35 ohms, and made of No. 16 S.W.G. wire, will answer the purpose. With a separate battery, one giving about 2 or 4 volts is the correct pressure to employ. When an electric piano is used, *i.e.* a mechanical piano worked by means of a motor, or any other instrument worked by means of a motor, which is not intended to be employed upon a 100-volt circuit, some suitable resistance must be used, unless the motor is replaced by one available for a 100-volt current. The best course is to ascertain the maximum current a low-pressure motor should pass, and to use the resistance in series in one of its leads; such a one that, if this resistance were short-circuited on the leads, it would pass a current no greater than that permissible to use with the motor. This is a very safe rule. Then, when this resistance is in series with the motor, resistance is taken out by means of a switch, until the desired result is obtained; observing always that the permitted maximum current shall not be exceeded. The proceeding may appear complicated, but if the experiment be conducted with an ammeter, it is done once and for all with that

particular motor. This method applies to all electrical apparatus, and the rule may be stated as follows :—

Examine size of wire upon the apparatus, and place such a resistance in series with the apparatus that a current no greater than that which the wire will carry can pass with the E.M.F. used, if placed in shunt between the mains.

In the case of electric cooking implements, the following result may be expected. The data are given in connection with water, since daily experience will permit anyone to judge of the differences with other liquids employed in cooking. It may be generally taken that, with apparatus as at present made, a pint of water, with 5 amperes, takes 8 to 9 minutes to boil; and, when current costs *6d.* per B.T.U., the expense will be one-third of a penny as near as possible.

In considering the difference in cost between electricity and gas, for lighting purposes, when electricity is at *6d.* per unit it is equivalent to gas at 3*s.* per 1,000 cubic feet; taking an 8 c.-p. lamp to replace a 5-foot gas burner. If the Electric Supply Co. makes a charge at half rate when current is employed for motive power and cooking, which appears to be the coming policy, and taking the average price in London of the current to be *6d.* per unit for lighting purposes, it is clear that it would be equivalent to gas at 1*s.* *6d.* per 1,000 cubic feet; although the heat equivalents are not equal. It is, therefore, not unreasonable to prophesy that electricity for heating purposes and motive power is likely before long to compete very severely with gas, unless the latter be lowered to at least 1*s.* *6d.* per 1,000 cubic feet. Notwithstanding the great advantages possessed by gas for heating purposes, the cost per hour of a 5-foot

gas burner and an 8 c.-p. glow lamp is the same, when the electric energy costs 6*d.* per unit and gas is 3*s.* per 1,000 cubic feet. There is some difference of opinion as to whether a 5-foot gas burner gives slightly more light than an 8 c.-p. lamp or not; also as to whether the ordinary 8 c.-p. lamp absorbs 30 or 33 watts. At any rate no authority gives a less value than 8 candles for a 5-foot gas burner, or more than 10 for gas such as is supplied in London. Gas varies very much at the different points where it is used, although it may be of one quality when it leaves the works. Tests made in summer or in winter show a difference, no two burners are exactly alike; the pressure in no two houses is the same, and, unless most accurate governors are inserted, the pressure must vary in every house: indeed in any house the gas pressure varies on every floor. Every 8-feet rise in level increases the pressure of the gas $\frac{1}{10}$th of an inch. The difficulty, therefore, of laying down a law for the light yielded by a 5-foot burner in a given house must be evident. The writer has never succeeded in getting more than 9½ candles from a 5-foot burner, when the arrangements were not of a character only possible in a laboratory. The consumption in watts, in the case of incandescent lamps, lies between 30 and 40; more generally the lower value. Reference is not made to what are termed "efficiency" lamps, which have short lives. Striking an average and eliminating the question of lamp renewal, the 8 c.-p. lamp and 5-foot gas burner not only cost the same per hour, but give the same light. In both cases, reckoning gas at 3*s.* per 1,000 cubic feet and electric energy at 6*d.* per unit, the cost of a 5-foot burner and of an 8 c.-p. glow-lamp per hour is less than one-fifth of a penny.

A few more words may be added, with advantage, on the question of comparisons between electric energy and gas.

A current of 10 amperes at a pressure of 100 volts will raise one pint of water from 60° Fahr. to 212° in 3·375 minutes. This is by theory, in practice the time will be 4 minutes. Now 10 amperes at 100 volts equals 1,000 watts or 1·33 horse-power. Consequently, an expenditure of 5·2 horse-power (theoretically 4·5) during one minute is necessary in practice to raise one pint of water from 60° Fahr. to boiling point. It is usual to employ a current of about 5 amperes at 100 volts in kettles and saucepans for ordinary use; hence the power per minute used is about 0·64 horse-power, and the time to boil a pint of water starting at 60° Fahr. will be 8 minutes. If 1 horse-power is applied the 1 pint of water will boil in about 5 minutes. Few persons consider the large amount of power necessary to heat water, and the above figures convey some idea. The cost to boil a pint of water under the above conditions, when 6*d.* per B.T.U. is the price, is 0·336 penny, say ⅓*d.*

Professor Fleming points out that the energy required to raise a pint of water from 60° Fahr. to boiling point is about the same as that required to incandesce a 16 c.-p. lamp for one hour.

The specific heat of water is very large, hence the reason why so much power is absorbed in heating this liquid. Now let the heating power of gas be considered.

In a table constructed by the late Dr. Letheby, one pound weight of ordinary gas is stated as being capable of lifting, one foot high, 7,262 tons. In round numbers, 33,000 foot pounds may be regarded as 14·75 foot tons. Hence, one pound of gas contains 492 horse-power for

one minute, if the gas is burned during this period. One pound of gas contains approximately 35 cubic feet, so that one cubic foot burned in one minute can exert theoretically 14 horse-power. From these figures it may be calculated that the quantity of gas required to heat 1 pint of water from 60° Fahr. to 212° is about 0·4 cubic foot. If gas costs 3*s.* per 1,000 cubic feet, the cost to boil a pint of water starting with 60° Fahr. is, say 0·0144 penny, compared with about 0·33 penny for electricity, that is, nearly 23 times less. Now electric energy can be used with a loss no larger than 10 to 15 per cent., whereas with gas the loss probably exceeds 75 per cent. when Bunsen burners are employed. Even under such unequal conditions, gas for heating power carries off the palm by more than fivefold. Calculating this problem from another standpoint, in the same tables it is stated that I cubic foot of gas will raise 650 pounds of water 1° Fahr., therefore 1 cubic foot of gas will raise 4·33 pounds of water from 60° Fahr. to 212°; 4·33 pounds of water equal 3·25 pints, consequently 0·3 cubic foot of gas will boil 1 pint of water under the given conditions.

It will be noticed that one calculation gives 0·4, and the last one 0·3 cubic foot of gas. The difference is due to working the results out approximately, to avoid many places of decimals. The mean 0·35 (costing about 0·012 penny) may be taken as sufficiently near, and whether one or the other result be considered, the fact that the heating power of gas is very cheap when compared with Electric Energy, is quite clear. Consider for a moment another problem, closely related to the above.

A good gas engine requires 17 cubic feet of gas per hour per indicated horse-power; 17 cubic feet of gas should

give 17×14 horse-power theoretically, that is 238 horse-power in one minute. Since the time occupied in consuming the 17 cubic feet of gas is one hour, the limit of power possible to be developed is approximately 4 horse-power, instead of 1 horse-power as in practice. From this may be seen the limit to which the efficiency of a gas engine can be brought.

It may be mentioned that, in round numbers, 1 ton of fair coal will produce 10,000 cubic feet of gas. From these remarks it is fair to assume that, for heating purposes and for power, gas ought to have a great future. What has been said in regard to gas might lead many to infer that electric heating and electro-motors are mistakes. There are numbers of cases where electric heating may have advantages over gas, particularly when the heating is required only at intervals of time and for short periods, also in cases where gas fumes must be non-existent. Electric energy for motive power, when distributed, is very economical. Electric ovens require about 25 amperes for the first 20 minutes, after this only 5 amperes, so that these apparatus are not extravagant as some people imagine. But when large quantities of heat are required over long periods, and when considerable power is required continuously, the expense of economical machines to produce the best results is no consideration; and then gas holds its own.

The writer has always been at a loss to understand why road cars should not use gas for motive power. Much time and money has been expended in the production of electrically propelled cars, whilst no efforts have been made in the direction of a gas-engine car. A steel cylinder, containing 100 cubic feet of compressed gas, is small, and weighs but 90 to 95 pounds. This

volume of gas can develop 5 horse-power for one hour. The main advantage to be gained by employing this method, is the ease with which gas supplies could be obtained, since the cylinders, ready charged, might be taken "on board" at various places, in the same way as coach horses are changed. A convenient form of gas engine is wanted, and the materials for this exist already. The whole organisation is ready, whereas for electric cars many changes must be introduced, for which time is necessary. A move is being made in this direction with oil engines, but compressed gas offers many advantages.

The power contained in a No. 4 sperm candle is extraordinary. Such a candle is to be found in nearly all households. Theoretically such a candle could exert nearly 125 horse-power for one minute, or over 2 horse-power for one hour. It could boil nearly 24 pints of water in 4 minutes with a starting temperature of 60° Fahr.

It may be seen from this what an enormous power is stored up in the fat of an animal.

In order to ascertain whether current is flowing in a circuit, a small horse-shoe electro-magnet may be inserted in the course of one lead, the wire upon this magnet being of the same section as the lead itself. If a current is flowing, a small piece of iron placed to the magnet poles will at once indicate the fact. A slip of paper should be pasted over each pole-magnet in order to prevent the piece of iron from sticking to the poles in consequence of residuary magnetism, if the current should cease to flow during the trial. The iron should be exceedingly soft in an electro-magnet used as a detector. Such a device, without going to the expense of inserting an ammeter, is convenient for a householder to

ascertain whether the servants have put out all the lights. The magnet may be put in some secret place, and may even have a picture placed in front of it, provided the poles of the magnet touch the canvas. On presenting to this magnet a small piece of soft iron, if it is found to be attracted, lamps must be alight; if there is no attraction, all the lights have been turned off.

The focus lamps, which were referred to in the preceding volume, may be employed in connection with magic lanterns, provided that a sufficient ventilation exists in the lantern case. It will also be advisable to place a water slide between the lamp and the condenser; the water in such slide being connected with a little reservoir outside the lantern in such a way as to admit of free circulation of the liquid. Without such a water screen there is always a risk of breaking slides, in consequence of the large amount of heat which these lamps give off. Small focus lamps might be used, but for projection purposes they would not have much value; and when it is remembered that one of the smallest of such lamps, which would prove serviceable, gives 100 candle-power, and takes 3 amperes at 100 volts, it will be seen that the power utilised in the lamp is two-fifths of one horse-power; and this is almost entirely converted into heat. In some cases the water slide may be replaced by a glass screen.

Very small focus lamps, with broad filaments, giving a light of say 8 candle-power, may be used advantageously in connection with the table microscope, provided the condenser is suitable. Such condensers can always be obtained, but before purchase a trial should be made with several condensers in connection with the focus lamp, so as to discover which is the most suitable focal

length. The surface of the lamp should be obscured, and a little pencil mark made at the centre, so that when a "bull's eye" is not used, the ground surface may be focussed by means of the mark on the plane of the object, in order to obtain a critical image.

In past years the writer has brought out various forms of incandescent lamps, the first of the series as long back as 1876. In the earliest ones, the carbon consisted of small rods about the size of the lead in an ordinary pocket pencil. They were placed in small air-tight glass shades; the oxygen was converted into carbonic acid gas by raising a small piece of carbon to incandescence in it; and then the carbon rod, intended to give the light, was incandesced. The life of such lamps, as may naturally be expected, was short. At the same time, they proved, for many years, of great convenience for working at the lathe after dark. At a later period, the author introduced several forms of lamp in exhausted globes, but with filaments quite different in character from those at present used; and he still believes that some of these modifications, for certain purposes, might be brought into service now with advantage. An instance may be given of one of them. A small and very thin hollow globe of carbon, connected with the circuit by the poles, was incandesced, so that a small globe of light was produced for the optical lantern and the microscope. Such a lamp is just the thing required for these purposes. At the time these lamps were introduced great difficulty was encountered in finding workmen who could make them, but such a hindrance should now have disappeared after so long an experience in the manufacture of lamps.

Mr. Tesla has been demonstrating how currents may be transmitted by the use of one wire only, and without

using an earth return. In all such cases it must be remembered that there is a return in reality, but the return is leakage through the air, except when true resonance results.

The late Professor Hertz shortly before his death published some extraordinary discoveries. He proved, what had already been suspected, that electric waves, like rays of light, could be reflected, refracted, and polarised, thus demonstrating the identity of electricity and light. The reader, who may desire further information on this point, is advised to consult Professor Oliver Lodge's book, styled "Modern Views of Electricity."

The passage of a current through one coil producing a current in a coil adjacent to it (which is known under the term of induction) is a fact which puzzles most people, who are also at a loss to understand why return wires have to be used. On the face of it this does not appear simple. The author himself felt the difficulty in his early experience, and tried to compare numbers of ordinary phenomena with these, to see if there was any analogy which would bring them more clearly to the mind. One of the simplest comparisons appears to be the following.

If the hand is moved through water in a basin, evidently a movement of the water or current is produced in some direction, due to the movement of the hand. In consequence there will be produced another current in the opposite direction to that in which the hand is moved, or in some other direction, to replace the water moved by the hand. There is thus a current set up in one direction mechanically, and a return current induced. The same result comes about when a train is in motion. The air displaced by the moving

engine necessitates a rush of air behind the train, to make good that which was displaced. These various currents may be regarded as the primary current and as the induced current. Looking at this idea generally, it may be concluded that any displacement or any movement must be followed by some secondary motion. In the case of the water moved in a basin, the current produced by the hand may be regarded as self-evident; but not necessarily so with the induced current, unless some apparatus is placed in the water to indicate it, or the water is discoloured in some way so as to allow this to be seen by the eye.

Now in the case of electric energy, if a current is produced in some direction, which probably is movement of ether, there will be a disturbance set up in the ether surrounding this current, which may be regarded as the induced current. If any apparatus is placed in the ether, whose motion has been induced, capable of indicating such a motion, the latter can be observed. Thus, taking a coil in which current is flowing, and producing a disturbance in the ether around it, when another coil is placed close to it, the disturbance affects this coil; and, in consequence, an observation may be made.

These explanations are not intended to appeal to the scientific reader, because a further elucidation would be necessary in order to bring it under the head of a scientific explanation. But, for the general reader, probably the *idea* of this method of realising how induction is produced will suffice.

Another instance may be given. When a steamer goes through the water, the induced currents which it sets up are shown by any little rowing boat that may be following in its wake.

Carrying this idea of induction to its utmost extent, although, perhaps, beyond the province of this book, and entering upon metaphysical grounds, the very existence of life may be but an inductive effect, probably an electric one. If it be assumed (and indeed it may almost be said it is proved) that all space known to us is pervaded by the ether, and that this ether is in motion, and if it be admitted that any apparatus of a suitable character will make apparent this motion in the ether, it surely is not unreasonable to suggest that, if any creature capable of life—if such a piece of apparatus is able to indicate ether motion—be placed in this material, or whatever ether may be—such an apparatus will record the movements, or, as it would be termed, indicate the existence of life. The living being may have the power of altering the motion of the ether in some way, producing the effect called *will.* To go a step further, it is known to all that some instruments are more delicate than others. Hence, if one living instrument is more delicate than another, it will be more sensible to the ether motion and possibly be better able to control it in some way. This may account for the reason why the higher animals are more intelligent than the lower ones, because those animals which have the higher organisation are more sensitive instruments. It might, therefore, be concluded that, if man could make any piece of organic apparatus sufficiently sensitive to indicate ether motion, the story of Falkenstein would be realised. So far, however, no man has ever succeeded in accomplishing this, except in mythology and fable. It must not be supposed that if this idea be true, a Deity must necessarily be non-existent. Energy must have come into existence in

the origin ; and because of our want of infinite knowledge the creation of this energy must be regarded as Divine.

The notion comes practically to this. Place any creature, capable of life, in ether and it will live.

It must be remembered that all matter contains ether, or, more correctly, all atoms are in ether.

There seems to be some *first impulse*, or other peculiar circumstance, which leads every animal and plant, as well as nearly every known inorganic body, to build itself up into definite shapes upon increasing in size ; *i.e.* to give a special case, the first atom, or group of atoms, which every animal starts with in its origin, must contain some peculiar *impulse* which leads it to build itself into a particular species, in the same way as crystals build themselves in accordance with certain laws. If, therefore, man is ever able to solve the question of *first impulse*—if such an expression may be used—there is no reason why organic matter should not be built up into given forms as metals are deposited electrically. In fact, there is no reason why a man should not be dissolved in a bath in England and be redeposited from a suitable organic solution in America, provided the *first impulse* can be given.

The author has conducted a large number of experiments with a view of ascertaining whether it is possible to deposit organic substances from organic solutions. So far he has not met with the success he anticipated, chiefly on account of the many difficulties which are experienced in passing a current through organic substances. It must not be supposed for one moment that, even when organic substances can be deposited electrically, that it by any means follows that life can be produced. There may be an almost infinite step between the two.

It must be borne in mind that the Deity has, by degrees, taken a position in nature further and further back. If, in the Dark Ages, a man had come forward and struck a match or done any other simple act, as we now should regard it, no matter how simple the act might be, he would be considered as possessed of the Devil; which is only another word for the supernatural. If such an act had been performed by the priests of those times, it would have been declared as one emanating from the Deity and not from the Devil. In other words, in ignorant times any result which was not familiar to the people was at once regarded as a supernatural feat: wicked for one class to perform, but welcomed from another, but privileged, class. As Science advanced, the enlightenment of the people kept pace with it; and the supernatural had, in consequence, to step back. The ability of man to assign the limit is a question only of time. The atheistic argument that Nature proceeds on common laws, and that all our actions are more or less dependent, not on ourselves, but on the circumstances surrounding us—depending on the action of others at the moment or in the past, and depending consequently on the formation of our characters and education, and also upon the qualities of our ancestors—is an argument that can scarcely be used as demonstrating that at no time was there a maker of the machinery. The fact that a clock goes regularly is no argument for saying that there was no maker of it.

Again, there enters the question that, if the writer's suggestions have any truth in them, would a future life be possible under such conditions? Naturally, this could only be answered in the affirmative upon the assumption that if ether, enclosed in a living being, has

its motion altered in some particular way, which gives to that being what is commonly known as consciousness, then, when that being, or indicating instrument, is removed, and the peculiar motion which has been given to the ether should continue, will that ether still possess consciousness? We know well that, if the vibrations of ether, producing the effect, say, of red light, are altered, by some well-known method, to vibrations giving blue light, this mode of vibration will persist, if not interfered with, so far as we know. It is, therefore, possible that the particular kind of vibration necessary in ether to produce a given phenomenon, about which nothing is known at present beyond that which is comprised under the word *consciousness*, may also be persistent. The reflection is a curious one, that should this idea have an existence, every soul—to use an every-day expression—which is here supposed to be simply ether vibrating in some special manner when separated from the indicating instrument, *i.e.* the animal—must probably produce, directly or by induction, ether vibrations of a similar character in all directions. This would lead one to suppose that infinite knowledge might be attained after death on such a hypothesis, if the ether vibratory antennæ, so to speak, have a definite communication with the central source. With a hypothesis somewhat of this nature it can easily be seen how thought-reading may become a thing of the future, without recourse to the devices essential for partial thought-reading as at present practised. It will be only necessary to discover a new means, if such exists, of being able to transmit (by induction or otherwise) the ether vibrations within the brain to the outside of the brain in space; or, if this now is so, to learn the method of indicating the

disturbance by means of the brain. If ever this should be discovered, it will be exceedingly interesting to know whether the consciousness of the brain will be extended beyond the limits of the cranium. If such a state of things ever comes about, speech will no longer veil the thoughts, but truth and justice will alone prevail.

The use of vacuum tubes is likely to play a large part in the future, but up to the present time this class of work has been regarded as having no practical utility; only now is its study coming to the front, and many discoveries will no doubt result in consequence. It is very possible that the very nature of electricity may eventually be decided by observations made with these tubes. Therefore, to enter into discussion as regards their scientific bearings would be premature; but it may be pointed out that they are now used to a considerable extent for decorative purposes.

It is frequently a matter of convenience to be able to turn on or off a current at a given time. This is usually done by means of a piece of clockwork, which actuates a switch. Fig. 31 illustrates a cheap form of clock cut-in switch. Another for cutting out, and very similar, is also made.

The writer has devised a more convenient form of clock for this purpose. The principle is such that at any given times a current is sent, by means of the clock, to a special form of switch, which may turn on lights, turn out lights, or do anything else that may be desired. In order to show one of the uses of such a clock, it may be mentioned that the one at Broomhill does the following work. When there is a dinner party, an arc light on a tower illuminates the carriage drives that the guests may easily find their way to the house; and for this purpose

it is alight for half an hour. When the guests depart, the arc lamp is relit for a similar period. The clock, at half-past seven turns on the lamp, and at eight turns it off; again, at half-past ten it turns the lamp on, and at eleven off. These hours are fixed in accordance with the custom of the neighbourhood; but the clock may be set to light and put out the arc lamp at any other hours, if preferred.

So far, nothing has been said in regard to the 3-wire

Fig. 31.—Clock Cut-In Switch.

system. It may prove of interest, therefore, to explain briefly how this works. Let it be supposed that the houses are to be supplied with current at 100 volts. At the central station two dynamos are connected in series; cables are taken from the two free ends of the dynamos; and the third one from between them, as illustrated in Fig. 32. The lamps are placed between the leads, as shown. It will be observed that the amount of current used on each side of the central, or equalising, wire is equal. This can be arranged in practice. The system

virtually becomes one of 200 volts, instead of 100. It follows, therefore, from what has been mentioned elsewhere in respect of the amount of energy carried by mains of given sections, that the outside two leads need be of much smaller section than would be required if the current had been one of 100 volts. Any difference in the amount of current supplied on each side of the equalising wire will be carried by this wire, and in general it will never be very large. Finally, the result is that to distribute current in a district on this principle

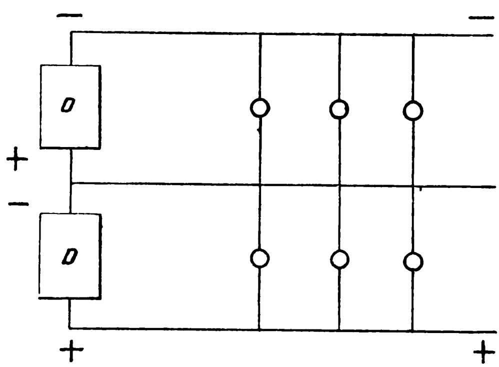


Fig. 32.—Three-wire System.

is not only easier, but a saving is also effected of nearly 40 per cent. in the weight of copper used in the mains.

The 3-wire system is applicable to direct and to alternate current, whether in the latter case transformers are placed in every house or not. In one method transformer stations are used, and then the low-pressure distribution is made on the 3-wire principle. The system is employed in the City of London, as well as in one or two provincial towns; and it appears likely that this method of town-lighting will be the one mostly

in use in the future, on account of its economy and simplicity.

It is evident that, when a district is supplied with current, there must be a fall in the pressure according as the houses are more distant from the central station. However large the mains might be, this result would always exist. Indeed the difficulty, if it could not be overcome, would entirely prevent the electric light being employed in towns. The equalisation of the pressure is brought about in a very simple way by means of feeders. These feeders are the mains which lead from the central station to the network supplying the houses. They are joined up with this network at such points that, instead of the fall of pressure being along one line, it is made to fall in several directions. A very simple example may be given. Supposing a street of a hundred houses at each side were supplied from a central station, then, instead of the feeder supplying current to the mains in the street being connected to them at one end of the street, so that there would be a steady fall in pressure from the first house to the last supplied, the feeder would be connected at the centre of the street; and consequently the fall would be between the centre of the houses and those at each end. By arranging feeders in a district in a suitable way, the difference in pressure between one house and another is very small. Reinforcement feeders also can be used.

To refer once more to the vexed question as to which is more economical for public supply, the direct system or the alternate current system, one large factor in the question has to be remembered. With the direct current, as the energy used upon the system increases, so does the

efficiency decrease. On the other hand, with the alternate current system the reverse is the case; because the proportion of loss, arising from the use of transformers, to the effective energy, becomes less as the current distributed increases. In both cases it must, of course, be understood that the amount of current used is limited to the maximum intended to be employed upon the system. One conclusion, at any rate, may be drawn from these considerations. In towns, where the demand for current is very considerable, the alternate system must have the advantage, not only for the reasons already mentioned, but also on account of less copper required in the mains; unless the central station is in the middle of, or close to, the district it supplies. In districts where the current demand is small, the advantage might possibly lie with the direct system; but in this case only when the distances between the central station and points of distribution are very close together. The only other method, which need be referred to, is the direct current distribution by means of direct current transformers in connection with a 3-wire system. Some maintain that this is more efficient than an alternate current system with transformer stations delivering into a 3-wire system. The latter is unquestionably more economical and reliable for the following reasons.

1. High-pressure direct-current dynamos are not so good at present as alternators.

2. The alternate current transformer is always at rest. The direct current transformer is always in motion, and requires constant attention.

3. The efficiency of the alternate current transformer is better as more current passes through, and at its worst point the loss is not very great. In the case of

the direct current transformer the machine must have an "efficiency characteristic" similar to a dynamo. This efficiency curve is far inferior and inverse to the efficiency curve of the alternate current transformer.

The only "saving clause," so to speak, for the direct current is that the average loss throughout the year might be less than with the alternate current system, seeing that the "load factor" is rarely over 15 per cent. at most stations. Since direct current stations have ventured to present themselves only in districts particularly favourable for their existence, the arguments of direct current advocates fall flat, especially when it is remembered that the alternate current system is adopted in troublesome districts for the very reason that the other method would have been unsuitable.

CHAPTER V.

ALTERNATE CURRENTS.

HERE and there, reference has been made to alternate currents, although this subject has not been dealt with, so far, in any systematic manner; because, in private installations, the direct current is, at present, chiefly used. In towns, the Supply Companies, for the most part, use the alternate current system; and for that reason a chapter briefly treating this particular type of current may prove of advantage to readers.

There are, at the present moment, many pieces of apparatus for the conversion of the direct current into the alternate one, and the reverse. When a house is supplied with the alternate current, it is sometimes required to use a direct current, particularly when small arc lamps are employed, since the direct current arc lamp is generally preferred. One of the best machines for converting the alternate current into a direct current is made by Mr. Ferranti. It consists of a specially wound alternate current motor of Mr. Brown's type, and a commutator. The motor runs synchronously with the periodicity of the alternate current, and by means of the commutator the alternate current is "re-dressed" into a direct one.

The subject of alternate currents is so large that, if a complete view of this subject is desired, Dr. Oliver Lodge's work entitled "Modern Views of Electricity,"

and Dr. Fleming's "The Alternate Current Transformer," should be consulted.

In the case of a direct current the pressure is all in one direction, but with an alternate current, the pressure is first in one, and then in the opposite, direction; these alternate changes in the direction of the pressure being extremely rapid. From these considerations it may be inferred that, if a 100-volt alternate current be used, and observed by the sense of touch, the shock will be equal to that given by a 200-volt direct current, because the successive changes of pressure from one direction to the other are so rapid as to be unnoticed by the brain, since this organ only receives the impression $\frac{1}{8}$ second after the event, and then it remains impressed for a short time. The sensation is that produced by the sum of a 100-volt pressure on the opposite side of a neutral line. It must therefore be concluded that, when alternate currents are employed, they should be regarded as if of double their given pressure in respect to their influence on living bodies. Moreover, the body offers less resistance to the alternate current.

It is very probable that, independent of the pressure question, other effects are produced by the alternate current upon living bodies.

If the frequency is exceedingly high, whatever may be the voltage, no ill consequences follow on touching conductors charged with such currents. Extraordinary effects are produced with high-frequency currents, and the reader who desires to study this question is referred to the work carried out by Mr. Tesla.

All instruments cannot be employed with alternate currents, and those must be excluded which contain permanent magnets, on account of the innumerable reversals,

which would rapidly demagnetise the steel. Also, all iron that may be employed in connection with alternate current apparatus must be very soft, laminated and ventilated, and the instruments have to be specially calibrated. Where subdivision of the iron is not possible, the pieces must be very small and the metal soft. The effect of the successive reversals of magnetism in iron causes it to heat, and this phenomenon is termed "hysteresis." The greater amount of the heat produced in the iron is due to the heavy currents induced, which is also the case with other metals. The effect of lamination is to interrupt eddy currents. Such currents are often termed "Foucault currents." Since the object to be attained by the alternate current apparatus, in most cases, is not to heat the iron it may contain, all energy consumed by the conversion of electric energy into heat is a waste of power; and every effort, in designing, is made to reduce these heating effects to a minimum. It might be supposed that the needles of the voltmeters would swing to and fro when employed with such currents, but the rapidity of the alternations is so great that no time is permitted, between each wave of opposite pressure, for the working portions of the instrument to change the positions they may have assumed; and although pressure is alternately positive and negative, a little consideration will show that a voltmeter needle will point the same way in either case. For the same reason, incandescent lamps do not alter their brilliancy, insufficient time elapsing for the filament to cool between the successive impulses. Besides, an impression upon the retina of the eye lasts $\frac{1}{8}$ second. Frequencies below 40 per second are unsuited for lighting purposes.

The only apparatus that interests the consumer is the

transformer, since it is usual with many companies at the present time to place one for every house.

Various other forms of apparatus relating to alternate currents have already been spoken of. A transformer is sometimes termed a "converter" and "secondary generator." This apparatus consists, in its most elementary form, of a core of iron, laminated, for the reason already given, which has wound around it two independent coils of wire, one having a high and the other a low resistance. The ends of the low-resistance coil are connected with the mains going to the house. The ends of the high-resistance coil are connected to the primary mains, which carry the current from the public installation. In one system the transformers for the different houses are placed in parallel upon the primary circuit. The other systems have already been alluded to. The house circuit, consequently, is quite distinct from the primary circuit. The only connection existing between the two is that each has a coil, in the course of their respective circuits, placed close together, in which a piece of iron (common to both) is inserted. In fact, a transformer is nothing more than an ordinary form of induction coil. There are numerous modifications of such apparatus in the market, but they are all constructed upon the same lines, the objects aimed at being efficiency, good regulation, and absence of heating.

The true discoverer of the transformer was Faraday.

The results produced by a transformer are extremely remarkable. If the various parts of the apparatus have been suitably proportioned, a current of high E.M.F., passing through the high-resistance coil, will set up a low E.M.F. in the low-resistance coil, enabling a current to pass through this circuit, which is in connection with the

house, proportional to the resistance which it may contain. And only so much energy will be drawn from the primary mains, through the transformer, as will be necessary to supply the energy required upon the house circuit; the volt-amperes, taken from the primary circuit on the transformer, being equal to those used on the secondary. There is, of course, a slight loss in the conversion; so that the whole of the energy in the primary coil is not converted for useful work.

It may be observed that the current which passes the primary coil is proportional to that passing through the secondary one. Hence, if the apparatus were perfect, when the house is using no current, the primary coil should likewise pass no current. This result is produced in consequence of the self-induction the apparatus possesses, and which acts like a counter E.M.F.; and the phenomenon is called "impedance." The continual rapid reversals of the alternate current render this circumstance not only apparent, but an important factor in its mode of working results.

Direct currents give the phenomenon of impedance, but it is momentary, except in the case of pulsating currents.

It is evident that, should by any chance the primary and secondary circuits upon the transformer come in contact with one another, by wear of the insulation or the destruction of any part, or even the whole of it, through overheating, by accident or otherwise, the high E.M.F. on the primary lines would be given to the house. In some patterns a metallic winding or sheet is interposed between the high and low resistance coils; this is earthed, and such a protection is fairly complete. Hence the necessity for thoroughly protecting all parts, in connection with the circuit, upon the premises, liable to be

touched. Equally desirable it is that the transformer should be kept in a fireproof, dry, and well-ventilated place and never be touched without turning off from it the primary current by the D.P. switch, which is always placed close by.

It is practically impossible to maintain perfect insulation on the high-pressure primary circuit, which is equivalent to saying that either one or both mains are in partial contact with the earth. Consequently, if a person were to touch one of these conductors, or any apparatus directly connected with them, the part touched would then be placed in connection with the earth through his body, unless he happened to be standing upon an insulating substance. And as this is generally not the case, by this action of touching, when both mains, or the main opposite to that which is being touched, have bad insulation, he completes the circuit to earth ; and an amount of current will pass through his body proportional to the resistance between the mains and the earth, which would injure him considerably, or even fatally.

When a shock is felt on touching a main, the faulty insulation which produces the result is not upon the main touched, but upon the opposite one, as already pointed out; and to ascertain whether the main examined was faulty, the opposite one must be felt. A faulty insulation might be observed when existing upon the main touched, provided a very considerable resistance existed between the point in contact with the hand and the place where faulty insulation existed ; but this would be extremely rare because conductors are usually made so that their whole length shall have but a very small resistance. Naturally, in the place of experimental testing for faults by means of the sense of feeling, which would in many cases prove

fatal, instruments are employed. The resistance of the body varies with the state of the skin, and it is higher when the skin is dry. When moistened with acid, the skin is very sensitive to electrical action; and when alkaline, much less so. These are the chief reasons why some persons can bear the application of higher E.M.F. than others.

Transformers generally produce a buzzing sound when current is passing through their coils.

There is a possibility of dangerous high pressure existing in a house without any indication being given of its presence; and fatal results might ensue if any part carrying current were touched. The conditions might be these: the insulation of the house circuit might be perfect, the two circuits in the transformer in contact one with the other, and one of the primary mains might have a leakage. Under such conditions, one primary main is in electrical connection with the house circuit, but, since the other primary conductor is supposed to have good insulation, no high-pressure current can pass through the house, inasmuch as the return circuit is not complete and the house pressure will be normal, as usual. But if in the house a main is faulty, the high pressure in connection with the secondary system now makes itself evident. The very fact of a person touching any portions of the conductors under the named conditions would give an earth, and he might suffer death in consequence.

The necessity for provision against touching any metal carrying current situated in houses is, therefore, important; because there is no guarantee against the combination of circumstances just mentioned taking place. Sooner or later the primary and secondary coils in the transformer will short-circuit, as these apparatus are now generally made. And although if an earth, good or

bad, were given to a house main through a person's body, under the conditions already stated, and a fuse were to go, death would very likely have supervened before the current was cut. There is only one certain way in which this danger can be obviated, and that is by placing metal plates, or winding, in contact with earth between the primary and secondary coils on the transformer, so that no contact could arise between these two circuits without touching the earth-plate first. Consequently, if the insulation on the primary circuit should become injured it would be put to earth; and that would destroy the primary fuses. The inmates would, therefore, save risking their lives at the inconvenience of darkness till the necessary repairs were made. Another method of protecting life is to earth one main, but this has hitherto encountered strong opposition on the part of insurance and telephone companies. The ground for fear entertained by the insurance offices is purely imaginary. The opposition on the part of the telephone companies is simply due to their indisposition to go to the expense of the twin-wire system, which would give so much satisfaction to their customers. Major Cardew, Mr. Hedges and others have devised safety arrangements, but they are delicate, and death might ensue during their action, so that life should not be made dependent on these or any other sensitive devices.

So many deaths have been caused by the use of high-pressure current that attention has at last been given to this point; and the large mains which are to supply current to certain portions of London from the big installation at Deptford, have one conductor placed to earth in order to render the primary system safe. This safety, however, is delusive, because the inner conductor naturally

comes to the surface in the station itself and at those places where connected to transformers. The mains were designed by Mr. Ferranti. The current in these mains has a pressure of 10,000 volts, and they consist of two concentric copper tubes insulated from one another, the outer one being placed to earth; inasmuch as its resistance is very low and no access can be obtained to the inner conductor, the danger to life is reduced, yet two deaths have resulted by contact with these mains.

The object of using tube in the place of solid core is that alternate currents tend to travel near the surface of the conductor, so that the central portion would carry but little current. Faraday was probably the first to show this phenomenon for static electricity. Professor Hughes and Lord Kelvin have proved it for alternate currents; but the reasons are not the same as in the case of static electricity. It must be borne in mind that the stress in the substance of any conductor is but small. The strain is in the insulation surrounding it, be this an insulating material or the air. Lord Kelvin and others have now proved that the energy of the current travels through the dielectric (insulation) and the conductor acts simply as a director. Hence the current enters the conductor from the outside surface. These are the views of the modern school. If the alternations are very rapid, no time is permitted for the current to penetrate far into the conductor, and, consequently, only the outer shell is used to convey the current. Hence, also the resistance of the conductor will vary with the speed of the alternations, since the useful area of the conductor varies with this speed. It is therefore evident that, if the frequency is sufficiently high, the current will not penetrate the conductor at all, but will travel through any

dielectric, such as air, with more freedom than if a conducting substance were used; and the mode of propagation will be more akin to radiation. The insulation may be compared to a steam-pipe which bears the pressure of the steam, and consequently is under great strain; but there is no true analogy. It will, therefore, be a question to be decided in the future, how long the various insulations now in existence will last, when placed under great stresses. Many laboratory experiments have been made for ascertaining the life of the material. But common sense would seem to indicate from experience in other matters that the conclusions derived from such experiments are not final, unless time enters as a factor. Copper itself undergoes a change by the passage of the current; its atoms are possibly under strain when in the condition termed electric, and after a time it assumes a crystalline form, rendering it brittle; and its resistance, while in that condition, no doubt would be increased. This alteration in structure may also possibly be due to the heating power of the current. Consequently, not only is the time, over which the insulation may be expected to last, a matter of uncertainty, but the copper conductors themselves may be perishable. One great difficulty with insulation is the weight of the copper within it, which tends to press its way through the material; or, as engineers term it, the cable becomes decentralised. In course of time the copper will work through to the exterior. With the best forms of insulation the period to produce this result may cover so long a time as not to enter as a factor into the question, except for a small depreciation fund. If the nature of the insulation is such that this action is rapid, the expense becomes a serious matter.

The alternations (complete cycles) in the mains of the London Electric Light Supply Corporation are 68 per second. The pressure of 10,000 volts is reduced to 2,400 volts at sub-stations, and finally to 100 volts at each house.

The City of London Electric Lighting Company employ 2,200 volts for the pressure in the primaries, being at a frequency of 100.

As already pointed out, Lord Kelvin and others have shown that the ordinary methods of measuring the resistance of leads has no value for unsteady and alternate currents, since they set up a spurious resistance which varies with the number of interruptions or alternations per second. The circumstance was first pointed out by Professor Hughes in his Presidential Address before the Institution of Electrical Engineers.

Alternators have been spoken of in the last volume. Alternators may be run in parallel, and used as motors. In the latter case they must be revolved first, and they will then continue to run. This might easily be imagined and predicted before experimenting to verify the circumstance.

The 'Brown' and Oerlikon motors are started by a special form of transformer, which makes the single-phase alternate current into a multiple one. When the motor is started the single-phase current keeps it running.

In transformer stations the transformers are banked, more or less of them being put into action as circumstances require, either automatically or by hand.

When it is desired to restrict the current, or to lower E.M.F., resistances are generally employed in the same way as in the case of direct currents. But another

method for accomplishing the same thing is by employing impedance or choking coils. Such an apparatus consists of a coil of wire containing a core of laminated iron, which acts as a retarder, and is equivalent to the insertion of a resistance or counter E.M.F. in the circuit. Even if one main, carrying an alternate current, is passed through an iron pipe, the current is impeded; but if both conductors are taken through the iron tube, the impedance is neutralised. If, in the first case, the tube had its circuit completed, an E.M.F. would be set up in it; which is not the case when both mains are placed together in the tube. These observations have an important bearing on laying cables in installations supplied by alternate currents, indicating arrangements which should be avoided.

The comparative advantages of the alternate and direct current systems have been discussed. There is, therefore, no need to enter upon that question afresh. With the alternate current system what is most required at present is a thoroughly efficient motor to work with any of the frequencies in use. Tesla, Brown, and others have brought out motors to use with these currents; but of all the alternate current motors out, it is doubtful whether their efficiency is as good as that of the direct current motor. These machines have now taken so important a place that the day cannot be far distant when the final solution will be found.

Iron in transformers appears to alter with time, and the efficiency of the apparatus becomes lower. This may be due to magnetic causes, or may very probably arise from the continual vibration to which iron is subjected in a core, when alternate current is employed.

This vibration may gradually render the iron crystalline and, in consequence, magnetically less efficient.

It should also again be pointed out that an alternate current may be at a pressure destructive to life; whereas, with a direct current at the same pressure, no harm whatever would be produced.

CHAPTER VI.

ESTIMATES.

It is almost impossible to give more than a very general idea of the cost of electric light installations, because the conditions under which they are erected differ to so great an extent. However, in order to guide those who are seeking information on the subject, a carefully compiled table has been prepared. This, together with the necessary explanations for understanding the basis on which the results have been obtained, forms the greater part of the present chapter.

Unless electrical work be thoroughly well done, and passed by competent persons other than the fire office inspectors, who have often not sufficient practice to understand every detail thoroughly, the result will not be satisfactory. In all cases, however, the fire office must receive a notice of the intention of the insurer to light by electricity; and it is well to ascertain if any special requirements have to be attended to before starting the work, as after-expense and trouble may thus be saved. If all be properly carried out, there is not the remotest danger of fire, but when inferior work is done, or the installation badly planned, an absolute danger will be introduced into the house. In the following estimates there has been an allowance of 25 to 50 per cent. margin of power; and this is not con-

sidered too much in practice, for the machinery and other portions of the installation are not strained, and in most instances extra lamps are added at future times.

The price of gas is reckoned at 3*s.* 6*d.* per 1,000 cubic feet (a usual price in the provinces); and coal at 20*s.* a ton. Each indicated horse-power of the gas engine is supposed to require 20 cubic feet of gas per hour, and each indicated horse-power of a steam engine (with fairly economical boilers), 6 lb. of coal per hour. The working expenses are not increased by the use of an accumulator, because, although there is a loss by their use on one hand, there is a saving in other ways; but under the head of sinking fund and interest an addition is made. The lamps are supposed to be the 8 c.-p. requiring 30 watts, and if 16 c.-p. are used, the numbers for the lamps must be halved.

When the earlier editions of this book were published, it was necessary to replace the 5-foot gas burner by a 16 c.-p. lamp. Such are the improvements which have been made of recent years in lamp manufacture, that the 8 c.-p. of the present day gives quite as much light as the 16 c.-p. lamp did when it first appeared in the market; and to all intents and purposes an 8 c.-p. obscured lamp gives the same light, as well as presenting the same appearance, as a 5-foot burner, used under the conditions generally found in a house.

A 5-foot gas burner will, therefore, cost about 1*l.* 15*s.* a year, on the assumption that it would be used 2,000 hours in the year.

To this must be added the damage caused by the use of gas at the rate of 2*s.* per burner, interest and sinking fund on fittings and piping, together with candles and oil (inseparable where gas is used) at 3*s.* per burner,

making in all, for single and grouped burners, *2l.* per light a year, when the gas is drawn from a public supply; but other expenses must be added for private works, such as interest and sinking fund. In this latter case also the cost of the gas itself will probably be more.

When gas is used, the consumption of oil and candle is always considerable, lamps being generally used in all sitting and bedrooms. To most people gas is intolerable in sitting and bedrooms, and even when the fumes are carried away—a matter difficult to accomplish—the bulk of the heat remains. Candles and lamps are also largely used for portable light, in houses where no electricity is employed.

To the mechanic or the poor man, gas has every advantage. He has no decorations to destroy. It is in the short days that he requires the light most, and the heat is then welcome. Such a man is accustomed to close workshops, and the gassy atmosphere to him is probably purer than that in which he does his daily work. The chief advantage of electricity for this class, especially to men who do piece-work, would be the possibility of employing its properties for motive power in their homes, renting motors for this purpose.

Professor Crookes once made a significant remark to the author. He said that had the electric light been universal at the present day, how wonderful would the invention of candles be thought, if suddenly introduced; thus enabling any person readily to obtain light in its simplest and most portable form, and without the use of cumbrous machinery, or the necessity of attaching the lamp to any fixed point by means of wires before it could be lighted.

In connection with light there is a curious physiological phenomenon which requires explanation. If, on a cold, gloomy day a few electric lamps are turned on, a sensation of warmth is immediately produced, though the temperature of the room remains the same. In expressing this sensation, some would say that the mind becomes more cheerful, and thereby the cold is less felt. This is not due to any variety of the form of light used, for any other illuminant would produce the same effect. But the change in one's feelings is not so easily observed, for the reason that the transition from darkness to light is not so sudden as with electric light; a more complex operation in obtaining the light has to be gone through. The chief reason why people feel cold, although the temperature of the blood remains unaltered, is that the blood does not flow so freely to the surface of the body. It is not improbable that the effect of rendering the mind more cheerful may stimulate the action of the heart, or that the effect of light on the brain may, through the nervous system, be such as to relax the capillaries, so that the blood flows nearer the skin. But, whatever be the reason, the result remains the same.

The question is sometimes asked, Is more light given by gas burned in the usual way, *i.e.* through gas burners, than in a gas engine employed for producing electric light? A gas engine requires about 20 cubic feet of gas an hour per ind. h.-p., which, in a properly designed installation, should give current for at least sixteen 8 c.-p. glow lamps. Consequently, for every 20 feet of gas burned in the engine, there is produced a light equivalent to about 130 or more candles, under best conditions probably 200 candles; since an 8 c.-p. lamp gives rather more light than its nominal power. A gas burner, made to pass 5

feet of gas at normal pressure ($\frac{9}{10}$ inch of water) per hour, gives about the same light as an 8 c.-p. lamp. Hence 20 cubic feet of gas burned in this manner will produce a light of about 32 to 36 candles. It is therefore evident that, when gas is employed to produce the electric light, the result is more than four to six times better than when it is burned in the usual way. The above remarks are made on the assumption that the quality of the gas is equal to that supplied in London, and, in speaking of candle-power, "standard candles" are implied. The light of a standard candle is about the same as that given from a No. 4 sperm candle, which is used in most houses.

In specially constructed gas burners, such as Siemens', Wenham, Cromartie, and others, far more light may be obtained from gas than in the common form of burner; but these special lamps, which are constructed on the regenerative principle, cannot be used universally on account of their size and expense. When, however, gas is burned in the best forms of this class of illuminating apparatus, there is no choice as to the light-giving power of gas in the two cases under consideration, unless the best conditions can be obtained, when the result of electricity is nearly double as good as gas.

It must be pointed out that, when a gas engine is employed for the arc light, the economy is vastly in favour of the electric light. For one break horse-power a light will be produced of about 2,000 candles, and the results are better per h.-p. as the power is increased.

Recent large gas engines require but 17 cubic feet of gas per break horse-power.

Electricity can be employed for heating purposes, by permitting coils of wire, or any other suitable apparatus,

to absorb electric energy, the result being production of heat. But the cost of the production of electric current at the present moment is an effectual bar to its use for such purposes on a large scale.

Supply Companies are now inclined to provide current at a lower rate for heating, cooking, and motive power. When this move in the right direction is accomplished on a general scale, there is no doubt that electric energy will be much used for those purposes.

Where water power cannot be obtained, the cheapest power on a large scale is steam; and in the best form of engine not more than 10 per cent. of the energy contained in coal can be converted into useful power. The loss during the successive conversions from steam-power into electricity, and again from electricity into heat, together with the passage of the current through the mains, is probably not less than 50 per cent. Consequently, 5 per cent., or very little more, of the energy contained in the coal is converted to a useful purpose. The ordinary domestic open fire is regarded as the most wasteful way of burning coal. Even those who are most opposed to this method of warming do not consider that the waste exceeds 50 per cent. This extravagant plan for the extraction of heat from coal is, therefore, ten times more economical than by producing the heat from it by electrical conversion. It must not be forgotten that, with the open fire, two kinds of heat are produced: the one being the ordinary form, such as that given by a closed stove (convection), and the other by radiation through the air without sensibly raising its temperature. This may be easily observed by anyone standing at a distance from the fire. The heat experienced is found to be consider-

ably greater than the temperature of the room. The late Sir William Siemens always pointed out this peculiar advantage derived from burning coal in open grates.

From the above remarks it might be thought that heating and cooking by electricity can never be a source of profit to Supply Companies. The following considerations may help to remove this misconception.

The machinery at the central station must be large enough to meet the maximum demand, and in practice this demand exists only for a few hours of the day, besides, also, for a portion of the year in some places. A large amount of capital invested is therefore lying idle for long periods; and if the machinery represented by this capital could be made to earn more than sufficient to pay working expenses and wear and tear, it would be a source of profit. It is here that the supply of current comes in for cooking, heating, and motive power; in point of fact, practice has shown that the supply of current for this purpose at a lower rate is profitable. There is little doubt that the day will come when gas engines will replace steam engines. The probability is that, when the right form of engine appears, it will not cost more than the steam engine; which is the case now for all sizes of gas engines made, but none exist for very large powers. The necessity of employing boilers will be dispensed with. Boilers require much attention, and are, besides their maintenance, a considerable source of expense; so that, by getting rid of this, the production of electric energy will be cheapened. Apart from such a question, the efficiency of the gas engine is from five to ten times higher than that of the steam engine. It may therefore be fairly estimated that, so far as the

cost of engine-power is concerned, the cost of production will one day be reduced to perhaps one-fifth or one-tenth of what it is at the present moment.

Then, again, if gas is made at common centres outside populous districts, there will be no need to obtain large pieces of valuable land, or to erect expensive buildings for storing coal overhead in towns. This will also help to diminish the cost of production of the electric energy. The efficiency of lamps likewise will probably be greatly increased in coming years, whether the lamps remain of the same type as at present or are completely displaced by new forms. At any rate, it is quite within the bounds of possibility that, in the course of the next twenty or thirty years, the cost of electricity per Board of Trade unit, instead of being 6*d.*, as it now is in most parts of London, will be reduced to 2*d.* or even 1*d.*, and still yield a large profit for the local authorities or the shareholders, as the case may be. On the other hand, although gas will be a thing of the past, so far as our homes are concerned, the industry will be more thriving than it is at present.

There is one very important point connected with gas engines that most people overlook: the fuel is carried to the spot free of expense and without trouble, at all times and in all weathers.

In the consideration of an accumulator, it is assumed in the estimates in every case that never more than 75 to 80 lamps can be lighted at one time from this source alone, though the installation may be for more lamps; because it is rare that a larger call is demanded when the machinery is not running, and the expenses are much increased when heavier discharges are required. Any number of lamps may be installed, but no more may be

in use at any one time than the maximum for which the installation was intended.

The steam engines in the table are all given of higher power than is actually required, in order to permit of a large margin for variations in boiler pressure, so as never to be short of steam; and since the power delivered varies with steam pressure, this gives a reserve, if the daily boiler pressure be below the maximum permissible.

A petroleum engine costs much the same to work as a gas engine, and the prices of these engines do not differ materially from the prices of the gas engine.

Under the ordinary conditions here assumed, 2*l.* per lamp has been allowed for wiring, switch, lamp, holder and fuse, including simple fittings.

If the installation is carried out in the most perfect style, including first-class distributing and fuse-boards, the expense may rise to 3*l.* per lamp, or even more, but as a rule such perfection is not required.

Elaborate fittings are not necessary, so that, if they are desired, their cost must be added; which will vary according to their number and to the taste of the owner.

The prices of the leading manufacturers for dynamos, engines, wire and all electrical requisites are much the same; and there is no reason for choosing one maker rather than another, provided that the most suitable and the best articles are obtained. It must be always borne in mind that some manufacturers make a speciality of certain classes of goods, and in order to secure the most modern and the most durable articles for an installation, several firms should be employed, permitting each to supply their special goods.

Some object to so many automatic appliances, but this is unreasonable, because failure scarcely ever occurs; and when this does happen, matters are no worse than if these appliances had not been there; a cut-out going indicates the event, and no harm is done. Mankind fails at least a hundred times to one, compared with the failure of a mechanical contrivance.

The public is still so ignorant in electrical matters that some scheme should be set on foot to enlighten them. Even professionals suffer from want of knowledge of the many forms of apparatus existing at a particular moment. In fact, nothing short of a complete museum of appliances, connected with electric lighting, is required, with competent persons to explain their various uses.

The table (pp. 212, 213) is corrected in accordance with present prices. The results have been compared with a large number of estimates, given by various contractors; and it is gratifying to observe that, in all cases, the estimates have worked out extremely close to the figures in the table. Inexperienced persons may, with confidence, use these tables to check contractors' estimates, leaving the engineer to see that the specification is satisfactory.

It cannot be too strongly recommended to those intending to put up the electric light, and who may not possess the necessary technical knowledge, that their best course is to employ a competent electric engineer to prepare the specifications, examine the contractor's estimate, pass the work when completed, and satisfy the insurance office inspector and any other authority; instead of following the usual course of committing the whole matter to the contractor only. The method of

proceeding here recommended will, in all cases, be found the cheapest and most satisfactory.

From the information given in this book a very complete specification could be drawn. No attempt will here be made to give a perfectly complete specification, because any statement intended to meet every possible contingency would be perplexing, and productive of no practical good. But, in order to make the present chapter complete, a skeleton specification is added, to serve more as a reminder for checking any given specification than for any other purpose. Any details can always be found by reference to some part of this book and the preceding volumes.

Skeleton Specification.

All work should be first-class.

Buildings, *i.e.* engine-house and accumulator-house, should be substantially built, fireproof, well-lighted, dry, and with good ventilation.

Machinery foundations should be placed on virgin soil and must be substantial.

Special precautions should be made against vibration.

In some cases the foundations must not be built up with the earth in contact, but a small air-space should intervene; a brick wall being built to keep the earth in position around the foundations.

Dynamos, alternators, engines, and other apparatus to be supplied by well-known makers and from firms of old standing.

No machinery or apparatus to be inserted which is new and untried.

In the case of gas engines particularly, select the maker who has had the longest experience.

The accumulator should be obtained from one of the well-known firms.

Mains between the engine-house and dwelling-house, or the point where the light or power is to be supplied, should by preference be a concentric cable of the highest insulation, lead-covered on the outside and drawn into a cast-iron pipe, with man-holes at such points as may be found necessary; the whole of this underground system being made completely water-tight.

It may prove an advantage to lay in the same pipe a telephone-wire for communication between the point of distribution and the engine-house.

Mains in the house, the small-wiring, and the casing should be first-class in all respects.

No wiring in the house to be embedded in the walls.

In those instances where the casing is let into the wall so that the cover may be level with the general surface, the casing must be painted or protected in some way from any moisture that might reach the wood from the plaster or other material of which the wall is made.

No wiring to be under floors, or in any position that may be inaccessible.

Where casing is found to be impossible, composition metal tubes may be employed, but none of greater length than will easily permit of being threaded by passing through it first a stiff wire.

Where alternate current is employed both leads must be drawn into the same metal tube.

The section of all cables and wires to be determined by a temperature test.

No. of hours used per annum. (Maximum possible)	No. of 8 c.-p. lamps in installation	Cost of dynamo	Fitting up dynamo, foundation, carriage, belting, switches, &c.	Nom. H.-P. Otto gas engine	I. H.-P. Otto gas engine	Cost of Otto gas engine, with water vessel	Cost of carriage, erection, pipes, foundations, &c., Otto gas engine	Cost of wiring, installation, lamps, switches, fuses, &c.	Nom. H.-P. steam engine (first-class)	Cost of first-class engine and boiler	Cost of steam engine-foundations, carriage, erection, &c.	Cost of simple governor	Cost of complete governors	Cost of automatic switches	Cost of switch-board for accumulator and instruments	Cost of accumulator only	Cost of erection, shelves, carriage, &c.	Cost of installation, no accumulator	Cost of installation, with accumulator
		£	£			£	£	£		£	£	£	£	£	£	£	£	£	£
2,000	50	35	15	2	4·5	71	30	100	—	—	—	15	70	30	40	100	20	266	386
2,000	75	45	15	3	6·5	81	35	150	—	—	—	15	70	30	40	160	25	341	526
2,000	100	50	15	4	9·8	95	40	200	—	—	—	15	70	30	40	180	30	415	625
2,000	120	55	15	6	13	112	45	240	—	—	—	15	100	30	50	200	35	482	717
2,000	150	60	20	7	15·6	124	50	300	—	—	—	15	100	30	60	220	40	569	829
2,000	200	75	20	9	19·5	136	55	400	—	—	—	15	100	30	70	250	45	701	996
2,000	50	35	15	—	—	—	—	100	2	120	30	15	70	30	40	100	20	315	435
2,000	75	45	15	—	—	—	—	150	3	170	50	15	70	30	40	160	25	445	630
2,000	100	50	15	—	—	—	—	200	4	200	55	15	70	30	40	180	30	535	745
2,000	120	55	15	—	—	—	—	240	5	220	70	15	100	30	50	200	35	615	850
2,000	150	60	20	—	—	—	—	300	6	240	75	15	100	30	60	220	40	710	970
2,000	200	75	20	—	—	—	—	400	7	270	85	15	100	30	70	250	45	865	1,160

N.B.—Expenses, whether a gas or steam engine is used, are the same.

From the above table the cost per Board of Trade unit may be ascertained. The average, when with a steam engine, is 9 pence. The cost per Board of Trade unit in a 50 lamp installation, whether When 200 lamps are installed each Board of Trade unit costs 4·7 pence.

Cost of auto. installation with accumulator	Average cost per lamp, no accumulator, capital account	Average cost per lamp, with accumulator, capital account	Average cost per lamp, auto. installation, capital account	Annual expense, actual outgoings, no accumulator	Annual expense, actual outgoings, with accumulator	Annual expense, actual outgoings, auto. installation, with accumulator	Average annual cost per lamp, working expenses, no accumulator, no interest or sinking fund	Average annual cost per lamp, working expenses, with accumulator, no interest or sinking fund	Average annual cost per lamp, working expenses, auto. installation, with accumulator, no interest or sinking fund	Annual cost, including interest and sinking fund, no accumulator	Annual cost, including interest and sinking fund, with accumulator	Annual cost, including interest and sinking fund, auto. installation, with accumulator	Average cost a year per lamp, with interest and sinking fund, no accumulator	Average cost a year per lamp, with interest and sinking fund, with accumulator	Average cost a year per lamp, with interest and sinking fund, auto. installation, with accumulator
£	£	£	£	£	£	£	£	£	£	£	£	£	£	£	£
471	5·5	7·7	9·4	95	103	106	1·9	2·06	2·12	113	130	140	2·2	2·6	2·8
611	4.53	7·0	8·1	140	150	155	1·87	2·0	2·05	164	187	198	2·18	2·5	2·6
710	4·15	6·25	7·1	148	161	166	1·48	1·61	1·66	177	205	216	1·77	2·05	2·16
832	4·0	6·0	7·0	167	180	185	1·4	1·5	1·54	200	230	243	1·65	1·9	2·0
944	3·8	5·5	6·3	190	200	205	1·26	1·33	1·36	230	257	275	1·47	1·7	1·8
1,111	3·5	5·0	5·5	230	240	245	1·15	1·2	1·22	280	301	322	1·4	1·5	1·6
520	6·3	8·7	10·4	95	103	106	1·9	2·06	2·12	117	136	142	2·34	2·7	2·8
715	6·0	8·4	9·5	140	150	155	1·87	2·0	2·05	171	193	205	2·28	2·57	2·7
830	5·35	7·45	8·3	148	161	166	1·48	1·61	1·66	185	213	224	1·85	2·13	2·24
965	5·75	7·1	8·0	167	180	185	1·4	1·5	1·54	210	239	255	1·75	2·0	2·1
1,085	4·7	6·5	7·2	190	200	205	1·26	1·33	1·36	240	270	280	1·6	1·8	1·86
1,275	4·3	5·8	6·4	230	240	245	1·15	1·2	1·22	290	320	335	1·45	1·6	1·67

working with a gas engine, is 8·5 pence per Board of Trade unit. The average when working the motive power is gas or steam, is at the rate of 9·7 pence.

All cables and wiring to be stranded.

Any cable or wire passing through a partition, or anything of a similar nature, should be carried through an earthenware pipe by preference.

The distance between all conductors having opposite polarities should be at least 1 inch.

Should it become necessary to place conductors under floors, the floor-boards must be screwed down over such places.

Switches, connectors, ceiling-plates, lamp-holders, and other fittings should be of the best construction, of non-combustible material, and insulated from the walls and ceilings.

No fitting to be used as a return, and all circuits to be insulated metallic circuits.

Twin wires to be well insulated, and no wall-connector to be placed without a switch.

Arc lamps and motors to be well protected.

In damp situations and in stabling, special precautions must be taken against damp and deleterious gases.

No sub-circuit should carry more than from 6 to 10 amperes.

All joints to be thoroughly well made, and outside the house placed in joint-boxes filled with pitch.

In the house there should be a main switch-board, and upon it a D.P. switch, an ammeter, a volt-meter, and the fuses of the branches which lead to subsidiary fuse-boards on each floor.

Every fuse-board to have a D.P. switch to cut off the current from that floor.

All lamps in bedrooms to be capable of being pulled up to a suitable height, and down to the floor, when fixed near toilet-tables.

Connectors to be placed by the bedside, and also where the inmates are accustomed to work.

All connectors, switches, and fuses to be placed within easy reach, excepting those in ceiling-plates.

All switches to be placed at a convenient height on the shutting doorpost inside the room, the exception being the switches required for subsidiary lamps, such as portable lamps.

Floor and table connections to be so arranged that, when not in use, a flap can be shut down over them for their protection and be level with the floor or table.

All apparatus, fuses, &c., should be labelled, so that memory may not be solely relied on.

All disputes to be settled by arbitration.

When necessary, time-clauses should exist.

For extras a schedule of prices should be added.

CHAPTER VII.

A BRIEF ACCOUNT OF THE BROOMHILL INSTALLATION AND OF THE WIRING AT GROSVENOR STREET, WITH RESULTS.

ELECTRIC lighting was commenced in an elementary manner in 1874, with primary batteries, to obtain a better light in the workshop at night. About a year later a Gramme dynamo was used. From that time, till 1881, continued advance was made in electrical science and in apparatus. Therefore, until 1881, it was deemed advisable to make no changes. In that year electric lighting assumed a more settled condition.

The Broomhill installation then underwent an alteration. A 16 candle Jablochkoff dynamo, with self-contained exciter, was erected.

In the following year much attention was given to accumulators for their supply to the public, and one of the first made was sent to Broomhill for lighting purposes, by the Electrical Power Storage Company. In fact, till 1883, there was no really good cell made. Those at present in use only differ in detail, but they now last well compared with earlier types; which is almost entirely due to a better knowledge of management. That is the whole secret of the matter.

Broomhill saw three distinct installations between September 1882 and September 1883; the Jablochkoff

dynamo disappeared, a Siemens 60 20 candle-power 50-volt machine was erected, and lamps were placed in the private sitting-rooms of the house. In February 1883, this was changed for a 100-volt dynamo, and great advantages accrued in consequence. A better light was obtained, and the number of lamps could be slightly increased. This was one of the first 100-volt installations. Four gas engines were put up during this period. In March 1883, another installation was erected, with a 6 horse-power steam engine, and two 50-light Siemens machines coupled. This installation ran admirably till November 1883. Breakdowns occurred, at first, for want of water to feed the boiler; but this was eventually remedied, and all went on smoothly.

The first accumulator was introduced in the autumn of 1883, and it proved a great boon.

This battery consisted of what was then termed 1. e.h.p cells, fifty-five in number. Endless devices were made in the workshops to be placed in the installation, so as to render everything automatic; and this was at last accomplished.

After the knowledge gained by past experience, it was decided to put up a model installation. This was done, and no hitch of any kind has ever occurred since the start in the summer of 1884.

It may be remembered that, about September 1883, the Electrical Power Storage Company declined to supply any more cells for a time; because it was their intention to introduce some improvements, which, however, in the end turned out to be mere "castles in the air." Broomhill, however, profited by this circumstance; for the Company undertook, as a favour, to supply a battery during that period on the understanding that, if it failed, they would

replace it free of expense. This battery eventually broke down, but naturally some experience had been gained through its use. In August 1884, the accumulator, sent in place of the old one, arrived; the cells being of the same size as before, but with thick plates, such as were termed "Regulator type."

This accumulator, however, proved unsatisfactory, and arrangements were made to exchange for it a new set of cells of the hanging type, with plates of the size "L." A new accumulator room, with all necessary arrangements, was built, to receive the new cells. (See Frontispiece Vol. I.)

In August 1885, this battery was erected.

In order to put up a larger accumulator, consisting of 108 cells, a new place was built in 1886, provided with many improvements; and up to this date no want seems to have been omitted.

There are five dynamos, three of them capable, each singly, to supply the largest current demand likely to be made; two of them are simple-shunt; one is a large compound-wound machine; one a compound dynamo capable of giving a current having a pressure of 100 or 60 volts at will (the former pressure is sometimes convenient for arc lamps); and the fifth is an alternator for about 100 8 c.-p. lamps. This last-mentioned machine is used only for experimental purposes. The arc-lighter was employed in connection with a large arc lamp on the top of the tower, which had an illuminating power of about 20,000 candles. At the present time, this lamp has been replaced by another, which really consists of two arc lamps in series; 15 amperes being used in connection with them, in the place of 40 to 50 amperes at the lower voltage required with the lamp which has been

removed. The object of this change was to enable the arc lamp to be employed with a small current, and off the accumulators at any time; no big resistances being necessary to reduce the pressure of the accumulator current from 100 volts to 60. In other words, the change has produced the economical result that, for all practical purposes, the light is more than sufficient, and a current of 15 amperes, instead of 40, does the work. Moreover, at any time of the day or night, the lamp can be turned on by means of a switch in the house in the same way as an ordinary glow lamp. Before the present arrangements existed, the arc lamp on the tower could not be turned on without a man being in the engine-house to run the engine at hours previously determined upon. Probably this is the only case at present of large arc lamps being turned on and off at a distance run by an accumulator, without the necessity of working any machinery during the time the lamp is at work.

From 1884 till 1890, large steam engines were employed. The engines, boilers, and other machinery were in duplicate. Each engine was Messrs. Marshall's 10 nom. h.-p., giving 56 ind. h.-p. as the maximum. The boilers were by the same makers; they were of the Cornish Multitubular pattern, 12 nom. h.-p. size.

Important improvements in gas engines were made in the year 1889. The price of coal went up, while that of gas went down. The advantage of a gas engine over a steam engine is very great. Less attention is required, and no boilers are necessary; so that many risks are eliminated. It therefore became a matter for consideration whether it would not be advisable, under the altered condition of things, to replace the steam engines by gas engines. A careful calculation was made

as to any probable difference in the working expenses of the two kinds of motive power, and the results were written down at the time, in order that, as a matter of interest, it might be seen whether the practical results verified the predictions. The calculations showed that the difference between working with gas and working with steam would not even be a penny. The sole consideration was the capital outlay in making the change; but since the installation was not erected for mere profit, it appeared worth while to try the experiment. Several years' experience with these gas engines, which are Crossley's Otto 14 h.-p. nom., indicating 33 h.-p., shows that the working cost of a gas engine is identical with that of a steam engine, when coal costs 25*s.* per ton, and gas 3*s.* 3*d.* per 1,000 cubic feet, with an illuminating power of 14 to 15 candles.

The advantage gained by the use of gas engines, and in consequence by the abolition of boilers, cannot be too strongly dwelt upon. At any time the engine can be started without notice. If the regular attendant is ill or is away for a holiday, the owner, or any one else, can start the engines without any difficulty, and without even soiling his fingers. The circulating water-tanks are of a large size, the oiling arrangements complete, the whole of the electrical portions of the installation automatic, and the self-starting gear of the gas engines simple and easy; so that all that has to be done, to start charging practically, is to turn a gas tap to light the ignition tube, turn a switch to start a motor, turn a wheel to cause this motor to start the gas engine, and then stop the motor, having turned on the necessary oil cups first. It is always a matter of surprise to those accustomed to go through the process of starting an

engine, as it is generally done, to see how easily the thing can be accomplished in this engine-house.

The countershaft rests on standards; the engines on one side, and the dynamos on the other side. The countershaft consists of two halves, which can be clutched together at pleasure. There are also special pulleys which can run as loose or as fast pulleys at will, by the removal or insertion of a bolt. These were made of the author's design, since the clutches would be too heavy and cumbersome to place in such large numbers on the countershaft. This countershaft runs another little countershaft, which works the constant-current governor. The pulleys on the small countershaft are so arranged that, whichever half of the main countershaft is running, notwithstanding that the governor is caused to work, the pulley connected with the other half of the countershaft stands still. Consequently this, what may be termed automatic arrangement, does not require the attendant to make any adjustment, or shift any belt, to run the governor; no matter which half of the countershaft he may be running, or whether the two halves are clutched together. Each gas engine has also a clutch upon it. Many of the details can be fairly seen in the second frontispiece of Vol. I. and in Figs. 4 and 5, Vol. II.

The convenient plan of placing resistances in the dynamo shunt circuit, in order to vary the E.M.F. or obtain a constant current, was probably devised and first used at Broomhill, as well as the counter E.M.F. regulating methods. Although the former method was deprecated at first, it was soon adopted, and now it is used universally.

There are about 600 lamps, *i.e.* equal to 600 16 c.-p.

lamps, for many are 100, 50, 32, 25, and 8 c.-p. The E.M.F. employed is 100 volts. The greatest number of lamps used at any one time rarely exceeds 200; and, together with these, the arc lamp, taking 15 amperes, and one or two motors. In the stables, cellars, and all conceivable places, as well as the house, electric lamps are to be found, so that no gas is used except for the gas engines, heating, cooking, and laboratory work. Almost all lamps are pendants. The switches in every case are placed upon the shutting doorpost inside the room. Every possible kind of work in metal or wood, from watch-work to large constructions, can be done in the workshop by means of machinery run by motors; almost every machine having one to itself. Photography is also practised by electric light, and for the dark room the electric lamp offers exceptional convenience. Numberless devices are in use about the house and elsewhere, advantage being taken of the benefits of the current for every imaginable purpose, such as heating water, ironing, even for the churning of butter, the working of a piano and mechanical toys.

In the laboratory small motors are exceedingly valuable. There is scarcely an experiment in which a use cannot be made of a motor: for revolving mirrors, for working induction-coil commutators, for regulating the intensity of a beam of light through sectors, for combining photographic images, and for numberless purposes so well known to those occupied with scientific investigations. Again, for the amusement of the uninitiated, the motor can be used for electric pianos, drums, phonographs, and a variety of amusing optical and other illusions.

All the electrical arrangements in and out of the engine-house are automatic.

The whole of the buildings were erected, and the electrical and engineering work carried out by the owner, without outside professional assistance, and by men trained on the spot.

There are probably 60 or 70 motors in use in the workshop and elsewhere. The end in view has always been to subdivide the power as much as possible, and thus avoid the employment of very large motors. An 8-in. lathe requires only a 1 horse-power motor to do the heaviest work which can be put upon it. Almost the only machine in a workshop needing large power is the circular saw. In order to cut through a 6-in. plank of oak with fair rapidity, about 4 horse-power is necessary. The brass-finishing lathes, and most of the small machinery employed in a workshop, require but a $\frac{1}{8}$ to $\frac{1}{2}$ horse-power motor. These figures will give some idea of the power needed for small machines. There is no motor existing at the present time more convenient than the Crocker-Wheeler. The motors in the workshop, from 1 unit size (equal to about 1 horse-power) to the 3 unit size, are of the Electric Construction Corporation make. The most delicate work can be done by means of electro-motors, which hitherto could only be done with revolving mandrils by hand, the foot motion having been found unsuitable. For such delicate work it is essential that the motor should not be fixed upon the same table as the machine, and that a small countershaft should be placed between the motor and the machine in order to run through two bands to eliminate vibration. In this manner, engraving, the turning of watch and galvanometer pivots, jewelling, and other fine work, can be carried out. The continued success of motors proves conclusively that all the difficulties, which so many have

imagined and have tried to overcome, are absolutely creations of fancy. In this workshop, sawing and turning of metal and wood; fret- and band-saw work; drilling, from three inches diameter down to holes the size of a hair, in metal and wood; grinding, polishing, engraving, the turning of watch and galvanometer pivots, jewelling, and every other imaginable kind of work, are all done by means of motors, and without the slightest disadvantage being experienced. On the contrary, the work is done cleaner, and the absence of noise is beneficial to the workman; he can stop the machinery in a moment, should the work require it, or his hands or clothes be caught; and thus he is saved from injury, the lathes having foot-brakes to arrest the motion quickly. This power has also been found far less expensive than the other kinds formerly in use.

The installation is put up throughout in a most perfect manner, and the buildings are very substantial and also well fitted. The maximum power is 800 16 c.-p. lamps, when both engines are running; and there are 110 23-plate (some are 25) cells at work. The cost of the buildings and installation has been about 10,000*l.*

A private gasworks, with piping and gas fittings, brackets and chandeliers, for the same number of lights, would have cost about the same, or even more. The sinking fund in either case would be much the same. But in regard to the working expenses, the electric light has proved more favourable than gas. This statement is made authoritatively, for there was a private gasworks at Broomhill before the electric light was instituted. It was at one time a question between building larger gasworks or adopting the new light, but calculations were in favour of the latter, and practice has justified

that choice. Accounts are kept of every penny spent on the light, as well as the number of ampere hours used. The cost-book has been accurately kept since 1884, and runs thus: for 1884, the total outgoings amounted to 165*l.*, being at the rate of 1*d.* an hour for every 8 c.-p. lamp; in 1885 the expenses were 181*l.*, or ⅝*d.* an hour per 8 c.-p. lamp, gas 3*s.* 9*d.* per 1,000 c. ft.; the total expenses in 1886 were 210*l.*, being at the rate of ¼*d.* per 8 c.-p. lamp, gas 3*s.* 3*d.* per 1,000 c. ft., when the current used for the motors was included. The expenses comprise wages, coal, oil, waste, washers, repairs, lamp renewals, insurance, and other charges. A six cubic feet gas burner costs about ¼*d.* an hour, when gas is sold at 3*s.* 3*d.* per 1,000 cubic feet; so that in 1886 the electric light proved as cheap as its rival, when sinking fund and interest are omitted. In the event of a private gasworks being used, these latter charges need not be taken into account; because they would be about equal for both methods of lighting. The reason why the expenses increased each year, and at the same time greater economy ensued, is twofold: first, as confidence in the electric light increased and the latter was used more and more, and finally, without stint, so that the installation was gradually worked nearer the point of greatest economy; and, secondly, numbers of improvements were introduced, in regard to management as well as apparatus.

For the year 1887 the working expenses were 183*l.*, and every 8 c.-p. lamp cost a little under ½*d.* per hour, or nearly twice more than in 1886. There were two reasons for this increase: first, the house was shut up nearly six months out of the year, during which time the installation was lying idle, although wages and other

expenses continued to run during that time; secondly, on account of special circumstances, no parties were given, and there was no staying company, so that there was a great decrease in the consumption of current.

The expenses since the year 1887, though very low, in no way form a basis for calculating the cost of the light, because the family had been a great deal away. The demand on the current was only made at intervals, and only during short periods. It may be mentioned that the standing expenses, if no light were to be used, are approximately 120*l.* a year, made up as follows: 88*l.* for wages, 10*l.* for gas-engine insurance, 3*l.* for fire insurance, and the remainder for sundries, such as materials for keeping the machinery and buildings clean, painting, and other small matters.

The expenses for the years 1886 and 1887 teach a good lesson. The extra expenditure of only 27*l.* halved the cost of the light; thus proving how necessary it is to base estimates, not on what an installation can supply, but on what amount of current is likely to be used on the average in the course of the year.

The cost per B.T.U. for 1887 was about 10*d.* per unit, as compared with about 5*d.* per unit in 1886, when the working of the system came nearer the point of best economy; and it must be borne in mind that this sum takes into account all renewals of lamps, minor repairs in the house, repairs to wiring, and all other expenses which are not included in the price per unit of public companies.

The outgoing expenses for 1888 were 141*l.*; for 1889, 152*l.*; 1890, 156*l.*; 1891, 152*l.*; 1892, 151*l.*; and for 1893, 170*l.*, when much more current was used. In 1890, steam was employed for the first half of the year, and

gas for the second. In 1891 and since, gas engines only were used. Dissecting the outgoing expenses for 1892, they are as follows: Wages, 88*l.* 8*s.*; oil, waste, &c., 1*l.* 12*s.* 3*d.*; the various insurance premiums, 12*l.* 2*s.* 6*d.*; lamp renewals, 15*s.*; 364,300 cubic feet of gas at 3*s.* 3*d.*, 59*l.* 3*s.* 1*d.* The number of gas-engine running hours were 684, and of running days 141. In adding up the dissected sums, it generally happens that they do not tally with the sum total of the outgoings for a particular year; but such discrepancy is usually under 20*s.*, and it arises from the fact that, at the beginning and the end of the year, part of the gas consumption and other small matters cannot be fixed to the very day. For instance, the engine may have run during the last week of the year and the meter-reading observed some time during the first week of the following year. The entry would, therefore, appear in the new year, although a portion of this gas consumption belongs to the old year. Attention is called to this, in order that distrust may not be placed in the figures given, in the event of some reader checking those given.

Although more current was used in 1893 than in many of the previous years, yet by careful working the expenses were reduced in some cases; thus the number of running hours was 604, the gas consumed was 385,000 cubic feet, costing 62*l.* 11*s.* 3*d.*, wages 88*l.* 8*s.*, lamp renewals at 4*s.* per lamp (which includes carriage), 1*l.* 10*s.* 6*d.* Since the reduction in the price of lamps no new ones had been inserted. Other items, 2*l.* 10*s.*

When the various results indicated are worked out, the working cost per unit on the average is approximately 6*d.* (intrinsic cost is 3½*d.*), but with interest and sinking fund, taken at 5 per cent. (except upon the accumulators, 100*l.* a year for the latter being the sum assigned, as found

by experience and working out at about 8 per cent. on capital value of the portions which deteriorate), the total expense per unit, considered from a commercial point of view, comes to 1*s.* 6*d.* But, since the installation is not in use for many months of the year, when the family is away, and the plan on which the installation is erected has economy in view, less current is employed than in most similar cases. If two and a half to three times the amount of current were used (the only additional expense would be the increase in gas consumption), it would be found that the cost per unit from the commercial point of view would drop from 1*s.* 6*d.* to 7*d.* It must also be remembered that nearly half of the time of the attendant is employed out of the engine-house, but no allowance has been made under wages for this. It must also be pointed out that, in calculating the interest and sinking fund, it has been taken on an assumed value of 6,000*l.*, and not on 10,000*l.*; because at least 4,000*l.* has been expended in work upon laboratory and experimental work, which would not enter as an item in ordinary country houses. Furthermore, the machinery is inserted on a larger scale, and has all been built in a better manner, and with more care, than that which would generally be in use. It is fair to conclude that the expenses of working the electric light, outgoings and all other expenditure being taken into consideration in regard to ordinary country houses, would not exceed 6*d.* per unit.

Considerably over 2,000*l.* was expended in experiments, before arriving at the present satisfactory position.

The cost of this installation may be divided into five parts. Each complete working-half cost 1,500*l.*; the cells

1,500*l.*, including all their fittings; extra dynamos, machinery, and so forth, 1,000*l.*; the engine-house buildings (which are extensive), 1,500*l.*; testing apparatus, lamps, wires, motors, apparatus, and other fittings, 4,500*l.*; making a total of 10,000*l.*, or thereabouts.

The author's house in Grosvenor Street is supplied by direct current from the Westminster Electric Supply Corporation. This company distributes on the 3-wire system. The pressure at the house is 100 volts. The metre-house is situated in a fireproof compartment in the area, where the company's metre and D.P. fuses are set; also a special D.P. switch of the author's design and a 16 c.-p. lamp to obtain light, when required.

The mains, 19/14 in size, pass on to the study, where the distributing board is situated. The latter is made of slate, and is cut up and mounted upon ebonite in such a manner that there is no connection between any portions having opposite polarities, excepting across the ebonite. Wherever portions having opposite polarities are situated near to one another, a piece of vulcanite fibre is placed projecting from the board above the level of any metal work, which prevents the possibility of an accident by making a short circuit when the fuses or connections are touched for any purpose. This board has upon it a D.P. switch and the branch fuses. On both the positive and negative branches there is a switch. Another switch exists to enable a supplementary arrangement to be placed in circuit with one of the mains. This supplementary switch-board carries one switch, by which one or two lithanode secondary cells may be placed in or out of circuit; so that the pressure of the supply current may be reduced 2 volts or 4 volts at pleasure. This enables the light in the house to be regulated at will. The main

switch-board has also upon it a connector for a voltmeter for testing. The board is contained in a glass case, the glass having at the required places holes drilled in, and covered by metal escutcheons to keep out the dust. In these holes can be inserted a key for turning on and off the switches. The board was constructed by the Acme Electric Works. From this board the secondary mains 7/16 in size, proceed to every floor. In the study there is a supplementary board, and upon it a switch which controls a fuse in one of the mains. These fuses consist of three in parallel; one a Cunynghame cut-out (set for 60 amperes), and two of fusible wire, of which one is for 10 amperes and the other for 90. This latter fuse is employed only in the event of a party being given. In such a case it is desirable to use the 90-ampere fuse as well, in order to prevent all possibility of the light being cut off when so many lamps are alight at one time. But, when the household is out of town the 10-ampere fuse alone is left in, and is capable of replacement by whomsoever is in charge of the house. A description of this piece of apparatus has already been given elsewhere. On the board also is placed a Paterson & Cooper ammeter, and the pole tester for testing the insulation of the circuit. Another supplementary board, carrying the author's insulation tester, and arrangements for placing a battery giving 100 volts upon the circuit for examining the condition of the insulation; also two D.P. switches, one for illuminating the tiled space at the back of the house and for illuminations, and one for illuminations in the front of the house. There is also a Kelvin electro-static multicellular voltmetre.

On each floor the secondary main undergoes distribu-

tion from a fuse-board, below which there is a D.P. switch to cut the current from the fuse-board when required. From each fuse-board the wires proceed to the various lamps on that floor, with a 7/18 cable, no smaller hidden conductor being used throughout the house. The cables employed throughout are the Indiarubber and Gutta Percha Company's highest insulation type. These are laid in white pine casing, shellac-varnished inside, and, when laid under floors, project beyond the skirtings. Thin sheet lead is placed over the casing, after the cover has been fixed on it, to protect the wire in the event of water being upset on the floors. Ceiling-plates and switches are of porcelain. These, together with the wall connectors of the author's pattern, as well as the brackets and fittings, were all specially made for the installation, and contain many improvements. It is evident that, with the exception of the fuses upon the secondary mains, and those upon the fuse-boards, others are not required, save at those points where lamps are attached. These are placed on the wall or ceiling, where the 7/18 cable stops. The twin wire employed is made by Messrs. Johnson & Phillips; it is well insulated, and in size is 40/40. All joints, outside the house, are arranged in such a way that they are made in one place, and put into a joint-box filled with pitch. The whole of the lamps, with very few exceptions, are single-light pendants, as at Broomhill, this method of lighting having been found most agreeable as well as economical; and in most cases every lamp has a switch to itself. There are portable lamp fittings in every room, and the total number of lamps installed is about 220. The expense has been considerable, in consequence of the large size of the cables used throughout. The cost has been

between 700*l.* and 800*l.*, which includes everything. In the event of removal to another house at the termination of the lease, the boards, instruments, fittings, and so forth, could be taken away. The loss would be in respect of the portions left, viz. the wiring only, which by itself has cost about 350*l.* The lease runs out in the course of fifteen years; and all the fittings being of superior manufacture, it is evident that this large expenditure was justified, as they will be as good at the end of that period as they are to-day. The usual practice of buying the cheapest for the purpose required is an unwise policy, because they are continually getting out of repair and are not worth removal to another place.

Many instances have come under the author's notice of installations which have had to be done twice over, simply because they were not properly done in the first place, and thus the owners were put to an expense far exceeding that which they would have incurred if first-class work had been done at the outset, apart from the immense inconvenience and danger to which life and property have been exposed. This consideration led to the installation at Grosvenor Street being carried out in so thorough a manner. All the lamps are obscured, thus equalising the light in a room to a greater extent than when clear glass ones are used, besides being agreeable to the eye. In fact, obscured lamps are really more economical to light with than clear ones; which is difficult to believe until the experiment has been tried. The pendant lamps have a convenience which is very great. Should it be found that a room is insufficiently lighted at its lower part, the pendant cords may be lengthened two or three inches and the desired result will then, probably, be obtained without the necessity of placing higher candle-power

lamps, or of increasing their number. Every circuit from the fuse-boards carries a current not greater than that necessary for seven lamps of 16 c.-p. The general arrangements, in regard to positions of switches, are the same as at Broomhill.

The lamps in the basement, passages, bedrooms, and stables, and the portable lamps, are 8 c.-p.; the others are chiefly 16 c.-p. The great improvement which has been made in 8 c.-p. lamps within the last few years has rendered it possible, by degrees, to replace all the 16 c.-p. lamps with 8 c.-p. as the former wear out.

When it is desired to replace a 16 c.-p. lamp by an 8 c.-p. lamp, without the fact being known to the household, which is sometimes desirable, there is a simple way to do this. If the 16 c.-p. lamp is allowed to remain until its light is very low, the change is readily effected and the lower power lamp appears to give more light than the old one, which is true in the beginning. In this way economy can be produced throughout a house without the inmates knowing the circumstance.

The author has introduced a very convenient form of reading-lamp with a self-acting counterpoise reflector, which he has found of great service when a light is required for prolonged work and the eyes need protection. It is a modified form of the parabolic reflector made by Messrs. Faraday.

In the designing of all switches, ceiling plates, connectors, and apparatus, special care has been taken that all portions in connection with the conductors are perfectly insulated from the hand, and in such a way that no parts carrying current can be touched without removing a cover or some equivalent protection; and in most cases gun-metal is used.

The switches are the Tumler of the Edison & Swan United Company.

In earlier days, the house in Grosvenor Street was supplied with current from the London Electric Supply Corporation. This Company supplies a current of the alternate type. At that period the supply was so irregular, and the pressure so varying, that the change to the other Company was made. The Deptford Installation now gives a satisfactory supply, which it was unable to do at the time when the writer obtained his current from them, on account of the temporary character of the works in New Bond Street at that period. When the alternate current was supplied, a Kapp regulator was found of great service for regulating the pressure. The present meter-house then contained the transformer, which was connected with the mains. The voltage of the primary current of that Company was, and still is, 2,400 volts on the London circuits; which supplies the buildings, reduced at the houses to 100 volts on the secondary. On the whole, although alternate current possesses many advantages for experimental work, the direct current is found very convenient for working motors; and there is a feeling of security against an accident, which might be due to the two circuits upon the transformer coming in contact with one another. The dangers, although remote, if every precaution has been taken, which might arise from such an accident, are practically eliminated when the current distribution is such as that employed in the City of London, viz. from transformer stations on the 3-wire system. The present price of current from the Westminster Electric Supply Corporation is sixpence per unit, and a small reduction is made when the quantity of current used is very large.

There are also a small workshop and a laboratory at the town house in which motors are used, and a supply of alternate current for experimental purposes, off the London Electric Supply Corporation mains.

It will be noticed that three things must be observed in wiring houses, and especially Rule 3, when the supply is from a public source, for, in this case, the potential employed on the primary mains when the alternate current system is employed, is usually very high, and therefore, dangerous to life; but, even in low-pressure installations, there are many advantages in observing this rule.

1. The conductors should be large enough to permit of any lamp, habitually employed, being changed for others giving a higher candle-power.

2. All conductors should be laid, and apparatus so designed as to eliminate the dangers of short circuit, or of other accidents which might lead to fire, and should be protected by fuses.

3. All portions carrying current should be insulated and carefully covered, to avoid shocks or for protection to life.

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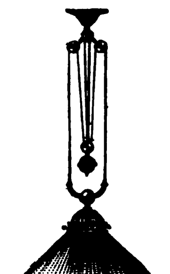

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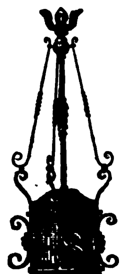

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